Saskatchewan

# A D F

## Agriculture Development Fund

# FINAL REPORT

**IMPROVING CANOLA MEAL QUALITY USING NEW PROCESSING TECHNIQUES AND CULTIVAR SELECTION**

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**CONFIDENTIAL**

Final Report to Agricultural Development Fund

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## 1. Abstract/Summary

Research was conducted to determine why amino acid availability in canola meal is less available and consistent than soybean meal. One stage of commercial processing (toasting) causes a reduction in available lysine content (20%) and total amino acid content (12%) and is responsible for the brown color of canola meal. Prior to toasting, meal quality was also more consistent. Therefore it is recommended that toasting be minimised and future work performed to determine if toasting can be eliminated. Some varieties of canola were resistant to heat damage, but toasting at the current level reduced meal quality in all varieties.

## 2. Executive Summary

Canola meal comprises approximately 60% of the seed and is sold as a protein source for animal feeds. Typically the meal sells at a discount relative to other protein sources due to lower amino acid availability and a higher level of variability. This discount represents a loss of approximately $27 million dollars annually to the Saskatchewan economy. The objective of this project was to determine why the meal is of lower quality and what can be done to improve it. The effects of commercial processing and genotype where investigated.

An initial experiment was conducted to examine the effects of current commercial processing on meal quality. Samples were collected from every stage of processing on three separate occasions. The plant that provided the samples is considered to be a relatively modern plant representative of most crushing plants. The samples were analyzed for amino acid availability in broiler chickens. One stage in the process, toasting, was found to have a dramatic effect on meal quality. It reduced lysine content by 12.4% and availability by 7.2% on average. Most of the other amino acids were affected as well.

Toasting changed the color of the meal from a light yellow color with some black specs to the typical dark brown color. Most customers find the dark color of the meal

unappealing as it imparts a dark color to the final diet. If toasting could be eliminated, the yellow colored product would be more appealing and may command a slightly higher price in addition to access to a larger market.

To determine if the effect of toasting is universally reducing meal quality, meal samples were collected from every crushing plant in Western Canada. Five crushing plants provided 5 samples of both toasted and non-toasted meals. One plant provided 5 meal samples and 1 untoasted meal. The remaining plant provided all the samples for the previously described study but was only able to provide one sample for this study. Actual amino acid availability was measured using broiler chickens and the results were similar to the previous experiment. Prior to toasting the meal had high amino acid availability and was not significantly different from soybean meal. After toasting however, meal quality was highly variable and had reduced amino acid content and availability. Prior to toasting each tonne of canola meal contained 21.2 ± 0.9 kg of available lysine, the most important amino acid, but after toasting it only contains 16.8 ±1.4 kg. Overall the sum of the available amino acids dropped from 307 kg per tonne of meal to 270 kg as a result of toasting. This represents a 12% loss in value of the meal. The amino acids that are no longer available end up in the feces of the animal and therefore have no value. Although this effect was studied using broiler chickens it is important to point out that the same effect is likely to be found in swine since they have very similar amino acid availability.

Almost as important as the loss in amino acid availability is the increase in variability. Currently no accurate method of determining amino acid availability in canola meal exists. Therefore, when nutritionists formulate diets they must incorporate a large and costly safety margin. If they don't, some customers will experience poor animal performance and business will be lost. The price paid for the product has to be discounted to compensate for the safety margin required. The industry clearly needs an assay to determine meal quality and guidelines for producing the product. In it's absence, the buyers don't know the quality of the meal they receive and the crusher does not know how much toasting has been or should be applied. Therefore another objective of this research was to develop a chemical assay to predict lysine availability in canola meal samples and to establish guidelines for production. The current assay of protein solubility in 0.5% KOH was found to be only moderately accurate with an $R^2$of 0.59 while Neutral Detergent Insoluble Nitrogen (NDIN) was the best predictor tested so far with an $R^2$ of 0.77. If the industry wishes to produce a meal in which 85% of the lysine is available the meal should contain no more than 10% NDIN or no less than 65% protein solubility.

Elimination of the toasting procedure would not only increase available amino acid content and visual appeal but also reduce processing costs. The toasting process consumes large quantities of steam energy and is therefore a costly process. Not only is the steam injected into the meal but the imparted moisture must also be removed by drying. We are currently recommending that the toasting temperature be minimized

but that the use of purge steam should not be suspended until further research has been conducted. Toasting canola to a brown color has been an accepted practice for over 25 years since it reduces glucosinolates and ensures no residual myrosinase activity remains. In our experiments toasting did reduce glucosinolates significantly, but, it is not known if this reduction is beneficial or neccessary. Myrosinase is deactivated during the cooking of the meal so there is no need to toast to eliminate them. Some consider toasting important to reduce the levels of residual hexane in the meal, but the manufactures of the equipment assure us it is not necessary to toast to reduce residual hexane content. However, until such time as these questions have been answered, we can not recommend the complete suspension of toasting. Therefore we recommend a study be undertaken to determine if toasting is necessary and to determine what modifications to the existing equipment, if any, are necessary to produce a low hexane, yellow colored, high quality product.

A scientist from the University of Saskatchewan, Rex Newkirk, will be visiting staff at each of the crushing plants in Western Canada in the Month of November, 1999. The objective of his visit is to discuss the results for each plant's meals and to discuss the benefits of reducing toasting temperature. Since the recommendations are simple and reduce processing costs, we anticipate the plants will quickly adopt them. Eventually the feed industry will recognize that meal quality is now improved but they will require detailed specifications and evidence of the improvements. We are therefore recommending that after the crushing plants have had a chance to adjust their systems, additional samples be collected and assayed for amino acid availability. The results from the new meals could then be used to educate customers on the new quality of the meal. As soon as nutritionists are comfortable formulating diets based on the new quality, they will be able to pay for the additional nutrients. With out this follow up study, nutritionists may not change their formulation practices and pay for the meal accordingly.

The effect of genotype on meal quality was also studied by examining 30 varieties from the Regional Spring Variety Trial of 1997. The major finding was that some varieties of canola are more resistant to heat damage. This would indicate that new varieties could be selected for tolerance to toasting. However, if toasting can be eliminated this would not be necessary. Therefore we do not recommend selecting for new varieties on this basis at this time.

In conclusion, toasting conditions in the commercial processing of canola meal are responsible for the dark color of the meal, the reduced available amino acid content and therefore for the discounted price of the meal. Until it is determined if the toasting is necessary, we recommend the degree of toasting be minimized. We also recommend measuring the NDIN content of the final product in order to monitor the quality of the new meal. Future research is needed to demonstrate the quality of the new meal produced and the validity of using NDIN as a predictor of meal quality. Once demonstrated, nutritionists can start formulating based on the new quality of the meal and pay for the product accordingly. Research is also needed to determine if the

meal can be produced and used in the non-toasted form. If toasting can be eliminated this significantly reduces processing costs, ensures maximum meal quality and produces a light colored highly desirable canola product. The usable or metabolisable energy (AME) of the meal was highly variable and only 50% of the variation explained by our research. We also recommend future research to optimize the metabolisable energy of the meal.

**Technical Report**

**Background**

An initiative, funded by ADF, Saskatchewan Canola Development Commission and the Canadian Grains Laboratory, was initiated in April of 1997 with the intent to improve the value of canola meal. Approximately 2 million tonnes of canola seed is produced annually in Saskatchewan, making it an important crop for the province's economy. The seed is crushed commercially to yield approximately 40% oil and 60% meal. The plant breeders and crushers have tended to focus on the quantity and quality of oil extracted and only considered the meal to be a by-product.

Canola meal is used as a source of protein, energy and minerals in the diets of most livestock species. It is a particularly rich source of the sulphur amino acids methionine and cysteine. Unfortunately, the meal sells at a discounted price in comparison to other protein meals. Generally canola meal sells for about 60% of the price of soybean meal even though it contains 75% of the protein. This is a significant loss to the industry and the province. For example, if you assume that canola meal is discounted 15% and trades for $150/tonne, approximately $22.50/tonne is not being realised. At 2 million tonnes of seed of which 1.2 is meal, this is a loss of $27 million annually to the Saskatchewan economy. The reasons for the discounted price are complex and not obvious at first glance but protein quality, metabolisable energy and shipping costs all contribute to the loss.

Although canola meal contains approximately 75% of the protein of soybean meal, it only contains about 60% as much "available protein". In the most basic terms, more of the protein in canola meal passes undigested into the animals feces than for soybean meal. If the nutrients are not used for producing meat, the consumer can not pay for them. Figure 1 shows the availability of lysine (the first limiting amino acid) in both canola and soybean meals. Note that lysine availability in canola meal is 10% less than that of soybean meal. Equally important however is the variability in lysine availability. Lysine availability (According to NRC, 1994 published guidelines) in soybean meal is 90% ±3 but canola meal is 80% ± 6%. Therefore, feed compounders use a large safety margin when using canola meal to ensure that the feed they produce is nutritionally adequate. Currently there is no quick and accurate method of assessing meal lysine availability in canola meal. If feed companies were able to measure

lysine availability on a routine basis, they would not have to use a wide safety margin and the meal would no longer have to trade at such a discounted value.

Another factor contributing to the reduced value of canola meal is it's relatively low metabolisable energy. The two most expensive nutrients in the diet are protein and energy so the more an ingredient contributes the higher it's value. Canola meal contains approximately 2000 kcal/kg metabolisable energy, whereas soybean meal contains about 2400. The exact reasons for the reduction in energy are not known but are due in part to the high level of fiber found in the meal.

The third factor contributing to the discounted value is shipping. Shipping charges for most commodities is virtually the same on a per tonne basis. If one is shipping long distances it is advantageous to ship nutrient dense material to reduce the relative costs per nutrient. For example if one ships a tonne of canola meal and soybean meal to Malaysia for $50/tonne. The one tonne of canola meal contains 360 kg of crude protein while soybean contains 480 kg. Therefore it cost ($50/360 kg*1000kg/tonne) $139/tonne to ship canola protein but only ($50/480 kg*1000kg/tonne) $104 for soybean protein. Obviously the end user has to discount the price of the canola meal, in this example $35/tonne of protein ($12/tonne of meal) to compensate for the additional shipping charges. The situation is even worse when one considers not only protein content but also available protein content. For example, even though one tonne of canola meal contains 360 kg of canola meal less than 280kg is utilised by the animal. Exactly the same scenario is true of metabolisable energy. For every tonne of canola meal shipped 2,000, 000 kcal of AME is delivered but for the same shipping charge one provides 2,400,000 kcal AME with soybean meal (20% more).

The combination of all three of these factors determine the final value of the meal. The objective of the research described herein was to determine what could be done to increase the value of the meal. To do this, the factors affecting meal quality were assessed and recommendations made. A second and equally important objective was to develop an analytical tool to assess meal quality quickly and accurately. Such an assay would allow crushing companies can adjust their process to optimise quality, plant breeders to potentially select for higher quality meal, and meal consumers could test the product received and pay based on actual quality.

## FACTORS AFFECTING PROTEIN CONTENT

Canola meal produced in Canada generally contains between 34 and 38% crude protein on an as received basis yet, seed grade *Brasica napus* canola grown in the Regional Spring Grain Variety Trial in 1997 at Canora, Saskatchewan averaged 39% crude protein on a fat free basis (Figure 2). Obviously the crushers are not cleaning to seed grade standard as the seed provided from this trial was. If the seed were to be cleaned more effectively prior to crushing the meal would command a higher value. However, this poses a problem since the more the seed is cleaned, the more seed is lost in the process. In addition, the crushers have to market the additional screenings. It

has been suggested by some, that the crushers may be cleaning but adding the screenings back at the end of the process. We collected meal samples at the marc and final stages from all the plants in Western Canada and in most cases the protein content of the final meal product was lower than that of the marc (Figure 3). This would indicate that the final product is being diluted to some degree, perhaps by the addition of screenings back to the meal. If this is the case, it would be very unwise to continue this practice especially for meal that is transported any distance.

## FACTORS AFFECTING PROTEIN QUALITY IN CANOLA MEAL

Several factors likely contribute to the final quality of protein in canola meal. The reason protein in canola meal is not as available as other protein sources such as soybean are not known. Classen and Clark (unpublished) found that lysine availability in five commercial canola meals appeared to be directly related to the amount of protein associated with the fiber fraction of the meal (Neutral Detergent Fiber Insoluble Nitrogen, NDIN). The source of variation in NDIN content was not known but it was speculated that it was related to the amount of heat applied to the meal during processing. Therefore, experiments were conducted to investigate the effects of steam heat on protein in canola meal. Two types of canola (*B.rapa* and *B. napus*) were oil extracted at POS Pilot Plant Inc.[1] using a minimum of heat. Small quantities, 50 grams, of these meals were then placed in envelopes made from filter paper. The meal was evenly distributed in the bag so the thickest area was no more than 1 cm to ensure steam could properly and consistently penetrate the sample. Samples were then heated for 15 minutes in an iso-thermal autoclave at 80, 90, 100, 110 and 120° C. All treatments were conducted in triplicate. The proportions of soluble protein and NDIN in the samples were then measured in duplicate.

The application of steam heat at a level of 100°C and above rapidly increased NDIN content of the meal (Figure 4). This confirmed that the application of steam heat during processing can increase the amount of protein associated with the fibre fraction. If the relationship between NDIN and lysine availability is correct, this would indicate that heating the meal at 100°C and above decreases lysine availability. The standard practice for the canola crushing industry is to toast the meal at approximately 105°C so it is possible that lysine availability is being reduced as a result.

Additional studies were conducted in order to define more precisely the effects of temperature and duration of toasting on the NDIN content of canola meal from *Brassica napus* and *rapa* varieties. The effects of this "toasting" in *Brassica napus* and *Brassica rapa* are shown in Figures 5 and 6.

[1] 118 Veterinary Road, Saskatoon, SK, Canada, S7N 2R4.

*Brassica rapa* was more sensitive to heat damage, but both samples showed similar trends. Toasting above 95°C resulted in significant increases in NDIN content. The higher the temperature the more sensitive the product to processing time. At 95°C the meal would have to be toasted for excessively long periods of time for protein damage to occur. In contrast, at 120°C a few moments of toasting results in significant damage to the protein.

Commercially it is generally accepted that temperatures at or below 110°C the toasting are not excessive. Our results suggest otherwise. From these results we would expect the nutritional value of canola meal for monogastric animals is reduced as a result of current processing practices. Figure 5 shows the highest and the average NDIN content observed in a set of samples collected from commercial processing plants. These samples will be discussed in greater detail later in this report, however, it is worth noting at this point that on average, commercial processing resulted in a NDIN content of canola meal of over 14%. Also notable is the observation that some plants were producing meals with a level of NDIN of only 9% which is similar to the meals toasted at 80-95°C. This provides evidence that it is possible to process the meal and remove hexane without increasing NDIN content.

Since it appears that processing may be responsible for the variation in lysine availability, we felt it would be useful to examine the effects of commercial processing conditions on meal quality. The first stage of the research was to determine if any particular stage of processing, including toasting, is having any affect on protein quality. To accomplish this, samples were collected from every stage of processing of a commercial processing plant on 3 separate occasions about 1 month apart. The products were then fed to broiler chickens to determine how much of the nutrients were utilised by monogastric animals. The stages of commercial pre-press solvent extraction are shown in Figure 7. Only those stages where the seed coat had been cracked were fed since the intact seed would likely have a reduced utilisation simply due to it's form. Therefore only samples after the flaking stage were analysed.

Amino acid content as a proportion of the protein, was not affected by any stage of processing prior to toasting. However, toasting significantly reduced lysine content in all three samples collected (Figure 8). Soybean meal contains about 6.2g of lysine per 16 g of nitrogen and canola meal is reported as containing about 5.6 g (NRC, 1994). However, prior to toasting the lysine content of canola meal is very similar to that of soybean meal. Not only was the amino acid content of canola meal reduced due to toasting, but the amino acid availability was as well. Crude protein digestibility, used as a rough estimate of protein quality, indicated that toasting was negatively affecting meal quality (Figure 9). As indicated by crude protein digestibility values, toasting reduced the availability of most of the amino acids in canola meal including lysine (Figure 10).

## TOASTING EFFECTS ON ENERGY UTILISATION AND MEAL COLOR.

In addition to a reduction in protein quality, energy utilisation (AME) by the animal also tended to be reduced by toasting (Figure 11). This is likely as a result of the reduced nutrient retention observed. In fact, samples needed for the determination of AME were not collected from the first set of samples, but after observing such significant effects on protein utilisation, we felt energy utilization may be decreased as well. As a result, fecal samples were collected from the second and third sets to measure AME.

Many users of canola meal complain about the dark colour of the meal. In many countries, corn-soybean meal diets have been the standard and the diet as a whole is normally light in colour. If canola meal is added to the diet, it imparts a dark colour to the diet and customers assume they are being sold an inferior product. In addition, canola meal is not usually included in the final finisher diets in the USA because it can result in higher condemnations at the killing plant. The plant inspectors look for crop contamination on the carcass of the animal, if the diet is of light colour prior to slaughter, then the crop contents will be of light colour and difficult to see on the skin or leaf fat. However since canola meal is very dark in colour, even trace amounts on the skin or fat are easily detected and the carcass condemned. Most assume that canola meal is of dark colour because the seed is normally black. However, prior to toasting the meal is primarily a yellowish colour (Figure 12). The untoasted marc has some black coloured flecks, which are from the seed coat, but the majority of the seed is yellow in colour. Therefore, in addition to improving amino acid content and availability, the elimination of toasting would produce a more attractive product visually.

## SURVEY OF SAMPLES OF MEAL FROM ALL WESTERN CANADIAN CRUSHING PLANTS.

The samples analysed in the first experiment were collected from a relatively modern plant with well trained staff, so we feel the negative effects of toasting are likely not limited to this plant. However, we felt it would be wise to test samples from every crushing plant in Western Canada to determine if this occurs at all locations. In addition, quality control staff at the first plant indicated that they had no effective analytical methods to assay amino acid availability. In fact, about the time we collected our first set of samples for the aforementioned experiment, they had some customer complaints about meal quality. As a result, they sent meal samples to several labs and the results indicated that the meal was not abnormal, however when we measured actual nutrient utilization it was clearly heavily toasted. Therefore we agree that a better assay for determining meal quality is required. It is impractical to measure actual nutrient retention on a routine basis so a chemical assay is needed. However, the current assays do not appear to be very accurate. So the objective of the next experiment was to determine if toasting is affecting meal quality in all crushing

plants in Western Canada and to develop a chemical assay which accurately predicts meal quality.

To accomplish this, canola crushing companies were approached and asked for five samples of meal before (marc) and after toasting. The meal samples had to be collected at least 2 days apart and the marc samples representative of the meal produced. All the plants agreed, but one plant was unable to provide samples due to staffing shortages at the time. The plant that declined to provide samples was the plant that provided the products tested in the first experiment, so we had already tested their product. A second plant misunderstood the request and only provided one untoasted product instead of five. Therefore, in total we collected 26 untoasted marc samples and 31 toasted final meal products. As in the first experiment, the meal samples were fed to broiler chickens to measure actual nutrient retention.

## AMINO ACID AVAILABILITY OF COMMERCIAL CANOLA MEAL SAMPLES BEFORE AND AFTER TOASTING

As expected based on the first experiment, toasting significantly reduced average amino acid availability (Figure 13). In addition to observing a reduction in amino acid availability, toasting increased the level of variability. Figure 14 shows the lysine availability of meal samples from individual plants and clearly lysine availability was inconsistent after toasting. Even within a plant, meal quality was variable.

We also measured lysine availability in a soybean meal sample and the lysine availability in the marc product was not different from the soybean, but after toasting canola meal was significantly lower ($P<0.0001$; Figure 15). Note the standard error of the marc was only $1/6^{th}$ of that of the final toasted meal. Clearly current commercial toasting conditions are reducing lysine availability and increasing variability. In fact, the reason lysine availability in canola meal is so much lower than the soybean meal is as a result of the toasting.

Not only was amino acid availability as a percentage of the lysine affected, so was the available amino acid content. Available content is calculated by multiplying the content in g/100 g meal by the percent availability. Therefore, available amino acid content reflects both the changes in availability and content. Figure 16 shows the available lysine content of the meal samples before and after toasting. On average every 100g of untoasted meal contained $2.12 \pm 0.09$ g of available lysine but after toasting only contained $1.68 \pm 0.14$g. Put another way, 1 tonne of untoasted canola meal contains 21.2 kg of available lysine but the same tonne of toasted product only contains 16.8 kg. This represents a serious loss in value since lysine is the first limiting amino acid in many pig and poultry diets.

The available content of almost all the measured amino acids (Figures 17-19) was reduced in the meal after toasting. Also shown is the sum of the available amino acids

(Figure 19). For every tonne of canola meal the untoasted product contains 307 kg of available amino acids whereas after toasting only 270 are remaining on average. That is a loss of an average of 37 kg of amino acids per tonne of canola meal that end up in the feces of the animal.

Also of concern is the ratio of lysine to the other amino acids. Animal diets require a balance of amino acids and generally canola meal is considered to be deficient in lysine as compared to soybean meal. For example soybean contains approximately 6.2 g of lysine for every 16 g of nitrogen while canola meal only contains 5.6 (NRC 1994). Further, if one considers only the available lysine as a fraction of the protein, the situation is even worse. NRC reports soybean to contain (6.2 g/16g N *90% available) 5.6 g of available lysine per 16 g of nitrogen where canola meal contains (5.6 g/16g N * 80%) 4.48 g. In our experiments, available lysine as a proportion of the protein (g/16 g N; Figure 17) averaged 5.4 and 4.3 before and after toasting, respectively.

## DEVELOPMENT OF A CHEMICAL ASSAY TO PREDICT AMINO ACID AVAILABILITY IN CANOLA MEAL

Since over processing leads to losses in amino acid availability and content it is desirable to have an assay to predict actual amino acid availability. The soybean industry primarily uses two assays to predict meal quality and degree of heating. The urease test is a simple assay and the enzyme tends to be denatured at approximately the same rate as trypsin inhibitors. Therefore, if the urease activity is low the trypsin inhibitors have likely been deactivated. If no urease activity remains in the meal then it has probably been overheated. Unfortunately, canola meal does not contain the urease enzyme so it can not be used to determine the level of heat applied. In addition, canola meal does not contain significant levels of trypsin inhibitors so it is not necessary to apply heat to denature them.

Another assay used is the protein solubility assay or NSI. Basically it measures the amount of protein that is solubilized in dilute KOH. As protein is denatured and involved in browning reactions the solubility of the protein is reduced. In the case of soybean, only enough heat is applied to denature the typsin inhibitors and lectins so the range of acceptable protein solubility is very narrow (Parsons et. al. 1991). However in the case of canola meal there are no defined anti-nutritional factors that need to reduced by heating, and therefore the objective is very vague. As a result the guidelines for acceptable protein solubility are very broad (>45%; Anderson Haferman et al. 1993). This leads to a large amount of variation in the degree of toasting applied in the industry. Quality control personnel are uncertain of how much they should toast the meal and are provided few guidelines.

Protein solubility, also called Nitrogen Solubility Index (NSI) or protein dispersability, is the most commonly used assay for determining canola meal protein quality. Little work, however, has been done to correlate protein solubility with actual amino acid

availability in canola meal. Therefore, in our experiments we measured protein solubility in 0.5% KOH in all of our canola meal samples. The solubility of protein did correlate with lysine availability with a $R^2$ value of 0.59 (Figure 21), but this would indicate it is limited as a predictor of lysine availability. If protein solubility is to be used as a quality control tool, we do however suggest that the guidelines be set at a higher level than is used currently. If toasting temperature were minimised, one could easily expect lysine availability of 80% and protein solubility of 52%. It would be desirable to produce a meal that has lysine availability of 85% but as long as steam purging and toasting is used it may be difficult to consistently achieve a protein solubility of 65%. A few commercial toasted meal samples tested where of this quality so it is possible but may be impractical to impose a such a high standard at this time.

Lysine availability was more accurately predicted by NDIN than protein solubility with an $R^2$ of 0.77 (Figure 22). Although still not a perfect predictor of lysine availability, NDIN could be used as a quality control assay. The assay is very simple and is semi-automated when using the Ankon fiber analyser. The system is inexpensive and easy to use. To conduct the assay, canola meal is weighed into a special filter bag, heat-sealed and placed in the analyser. One hour later the bag is removed dried and assayed for residual protein. It would be entirely feasible for a crushing plant to collect samples through the day and determine if their desolventizer toaster is set appropriately. Based on our finding we suggest that the maximum NDIN value of the meal be set at 10% to ensure that meals produced have at least 85% lysine availability. If adopted by the industry, a higher quality and more consistent product would be produced.

Other predictors of meal quality are also being tested at this time. One such assay is NIR or Near Infrared Reflectance. This is one of the simplest and quickest assays available. Basically the sample is placed in a machine, scanned for a minute and the results printed. NIR is commonly used to measure protein and moisture in grain samples and has been widely accepted by the grain and feed industry. We are collaborating with the Canadian Grain Laboratory to determine if NIR could be used for this purpose. To date, they have not had time to determine if NIR will be an accurate predictor of lysine availability. Once this work has been completed, we will forward the results to be appended to this report.

Another assay being currently tested is the use of lysine dye binding test. The assay is more involved than that of NDIN and NIR but it specifically targets reactive lysine and therefore may be a good predictor of lysine availability. Unfortunately, at the time of this writing, work was still proceeding on this issue and the results will have to be forwarded with the NIR findings following the submission of this report.

## THE USE OF A CHEMICAL PREDICTOR TO SELECT FOR VARIETIES WITH HIGHER PROTEIN AVAILABILITY.

Plant breeding has been used to dramatically change the properties of canola. It is used to increase not only agronomic traits but also seed composition. It may be possible to select for varieties with higher amino acid availability but in our research, we found that prior to toasting all the samples collected had high amino acid availability. There is room to further improve this availability, but it would seem more likely that plant breeding could be used to select for varieties that are resistant to heat damage if plants are going to continue to produce toasted meals.

To determine if some varieties are more resistant to heat damage, we collected seed from the Regional Spring Grain Variety Trial conducted in 1997 by the University of Saskatchewan, and measured the change in NDIN content as a result of heat treatment. Every effort was made to mimic the conditions of the commercial desolventizer including direct contact with steam. In total 30 varieties were tested including 10 *Brassica rapa* and 20 *Brassica napus* varieties. After heating at 110°C for 10 minutes, and estimating lysine availability based on NDIN content there was definite variation in susceptibility to heat damage. Lysine availability in the *Brassica rapa* varied from 75% to 65% (Figure 23) while most *Brassica napus* ranged from 70% to 65% (Figure 24). This would indicate that part of the variation in lysine availability in the toasted meal samples is likely due to differences in susceptibility to heat damage. However, we would suggest that it would be better to minimise the degree of toasting rather than select for varieties with higher tolerance for heat.

## EFFECTS OF TOASTING ON GLUCOSINOLATE LEVELS IN CANOLA MEAL

The original rapeseed varieties, from which canola was derived, contained high levels of glucosinolates which are known to be goitrogenic when fed to mono-gastric animals. However since the release of the first low glucosinolate variety of canola over 20 years ago, breeding has steadily reduced the level of glucosinolates. Initially toasting was thought to be beneficial since it reduced the glucosinolate content of the meal. Indeed at high inclusion levels in the diet, the level of glucosinolates found in the seed can reduce performance. Classen and Clark (1991) found that including 30% canola meal in a broiler diet reduced performance but inclusion of low glucosinolate canola meal did not. Therefore it would seem to be beneficial to reduce glucosinolate levels in the meal, although the dietary inclusion level was quite high in that research.

Toasting has been shown to reduce the level of glucosinolates in canola meal and indeed the levels of the glucosinolates in the meals collected from commercial crushing plants in Western Canada were reduced (Figure 25). Toasting reduced the level of the indole glucosinolates (Figure 26) more than aliphatic (Figure 27) but

toasting significantly reduced both. At first look it would seem that toasting is beneficial since it does reduce the level of the glucosinolates. However, one has to ask the question, is the level of glucosinolates found in today's varieties high enough to be toxic and if they are, should we be toasting to reduce glucosinolate levels at the expense of protein quality. The experiment conducted by Classen and Clark (1991) only showed a reduction in performance with the inclusion of 30% canola meal. At lower inclusion levels no effect was observed. This would indicate as long as the inclusion level of canola meal is at a reasonable level, the glucosinolates will not be toxic. It is impractical and difficult to formulate diets with 30% canola meal, in fact most users don't use more than 10% in the diet. Therefore it would seem unwise to further reduce the level of glucosinolates at the expense of protein quality when it is not necessary. Further, it has been proven that breeding can further reduce the glucosinolate levels so even if one wanted to use high inclusion levels, it would be wise to decrease the glucosinolate by breeding rather than by toasting.

The first variety of low glucosinolate canola contained 30 umol/g of aliphatic glucosinolates but the untoasted meals assayed in this experiment only contained an average of 10.6. Assuming toasting destroys 40-50% of the glucosinolates in the meal, the untoasted canola products produced today contain less glucosinolates than the toasted meals produced from the first varieties of canola. Therefore, it would seem it is no longer necessary to toast the meal to reduce the glucosinolate levels.

## FACTORS AFFECTING METABOLISABLE ENERGY CONTENT OF CANOLA MEAL

The amount of energy in canola meal utilised by poultry (Apparent Metabolisable Energy , AME) is low relative to soybean. As in the case of protein, the end user can only pay for those nutrients that are effectively used by the animal. As a result, the low AME reduces the value of the meal. Therefore, it would be beneficial to improve the AME of the meal.

The main objective of our research was to look at protein quality and the factors that reduce it, but we also looked at energy utilisation in canola meal. To investigate factors that affect energy utilisation, the AME of all the canola meal samples collected was determined.

Metabolisable energy was found to be highly variable between samples (Figure 28) but unlike our findings with protein quality, toasting did not consistently affect AME. The fact that some of the samples had relatively high AME values indicates it is possible to produce a product with a higher metabolisable energy.

Several factors likely contribute to the AME of canola meal. Canola meal contains higher levels of fiber than soybean meal which account for part of the reduction in AME. However, in our experiment, the level of neutral detergent fiber in the final

meal did not correlate well with the metabolisable energy content of the meal (Figure 29). This would suggest that other factors had more of an effect on AME than fiber.

Most of the oil is extracted from canola seed during commercial prepress solvent extraction, however the gums are added back to the final meal. Prior to the addition of the gums, the residual oil content of the meal is about 1.5% and an additional 2% gums is added back after toasting. Since the fat and gums are high in metabolisable energy, they will contribute to the final metabolisable energy of the meal. In our experiment there was a weak but significant correlation between the ether extract (fat) content of the meals and their metabolisable energy (Figure 30). The fat content of the meal explained about 8% of the variation in AME of the meals. Clearly the higher the level of fat remaining in the meal the higher the AME and the value of the meal. However, it is unlikely that the processors would wish to leave too much oil in the meal since they can capture more value by selling it to the human vegetable oil market.

Since the main nutrient in canola meal is protein much of the metabolisable energy is derived from the retention of the amino acids. Therefore, meals with highly available amino acids should have a higher AME value. In our study this was found to be the case as AME of the commercial canola meal samples was positively correlated with available amino acid content as measured in broiler chickens (Figure 31; $r = 0.375$).

Traditionally one assumes that the metabolisable energy content of an ingredient is derived from the utilisation of starch, protein and fat. However canola meal does not contain starch and the utilisation of protein and fat only accounts for about 46% of the variation in AME so some other constituent(s) must also be responsible. Canola meal contains about 8% sucrose and approximately 1% glucose (Simbaya et al., 1995). These saccharides likely contribute to the metabolisable energy of canola meal but the level of variation between meal samples is not known. Therefore we measured the content of ethanol soluble reducing sugars. Sucrose is not a reducing sugar and therefore not quantified by the assay used, so we also treated the sample with invertase prior to the assay. This enzyme cleaves sucrose into glucose and fructose so that they will react in the reducing sugar assay. The levels of glucose and other free reducing sugars were low as expected but did vary considerably between samples (Figure 32). Toasting increased the level of the reducing sugars significantly in all cases. The additional reducing sugars are likely the result of saccharides being released during the heating of the meal. Another possible source of reducing sugars could be from any screenings added back into the meal at the end of the processing line. The samples could be measured for starch content to determine if screenings are the source of additional reducing sugars, but it was felt this was not necessary at this time.

There was no significant correlation between non-invertase treated reducing sugars and AME (Figure 33). No effect was observed probably because the overall contribution of glucose to the metabolisable energy content of canola meal is relatively small. Therefore variations in content would only change AME slightly if at all.

The level of sucrose and other non-reducing oligosacharides released by invertase also varied between meal samples (Figure 34). Unlike the trend observed with glucose, toasting did not consistently affect the level of sucrose and other oligosacharides (as measured by reducing sugar assay with invertase) in the canola meal. However there was a significant correlation between AME and reducing sugar content released by invertase (Figure 35). The correlation was weak but did account for about 5% of the variability in AME in canola meal. Some of the reducing sugars such as arabinose, xylose and ribose, which are measured by the assay, are of no nutritional significance and would therefore reduce the ability of this assay to predict AME. In future studies, it would be desirable to measure the contribution of specific mono- and oligo-saccharides to the AME of canola meal.

In total only about 50% of the variation in AME is explained by the variability in fat content, available amino acid content and sucrose content. Clearly other factors are also affecting the metabolisable energy value of canola meal and so further research is required to help the industry produce a meal with a higher and more consistent AME.

## GENETIC SELECTION FOR CANOLA VARIETIES WITH HIGHER AME VALUES.

Since the level of sucrose, as analysed by invertase treated reducing sugars, was positively correlated with AME we measured the level in 30 varieties of canola from the Regional Spring Grain Variety Trial 1997. The level of reducing sugars released by invertase (primarily sucrose) varied considerably between varieties (Figure 36). This indicates it may be beneficial to select for higher levels of sucrose provided it does not increase at the expense of protein.

Since available amino acid content is directly related to AME it would be beneficial to select for this trait. Since toasting is the main source of variation in amino acid availability it may be difficult to select for. However, we would suggest that new varieties should be selected with the highest possible protein content. Increasing the protein content should increase AME as long as the meal is not heavily toasted.

Since only 50% of the variation in AME is explained by the traits measured in this project, significant room is left for improvements. We suspect that the level and type of soluble dietary fiber and oligosaccharides likely contribute to the variation in AME of the meal products. Further work is required to identify the oligosaccharide content of the seed and to determine if genetic selection can be applied to increase the level of those that positively influence AME.

## RECCOMENDATIONS AND FUTURE RESEARCH

The objective of this research was to determine which factors contribute to reduced amino acid availability and variability in quality. The data clearly show that the level

of toasting used commercially is responsible for the loss in protein quality and therefore the value of the meal. It is our recommendation that crushing plants minimize the level of toasting applied. If adopted, this will result in a higher quality, more consistent and valuable meal product. Since the seed is 60% meal this should also result in an increased value for the seed. We would suggest that the meal should not be toasted at all and a light colored high quality protein product sold, however, the non-toasted product needs to be tested in large scale trials first. We are comfortable, however, suggesting that the toasting temperature can be reduced significantly and new guidelines set for either protein solubility or NDIN levels.

The current feed industry is accustomed to receiving less than optimal canola products and will need evidence the new product is higher quality. Until the nutritionist is comfortable assuming 85% lysine availability and higher content, they will continue to formulate based on past assumptions. To assist the industry in making the transition, we propose the meals should be tested after the crushing plants have had a chance to adjust their system. We would then determine amino acid availability and animal performance based on the new processing method. We are currently arranging to meet individually with personnel at each of the crushing plants to show them the results and explain how to maximize meal quality. Then in the month of December we are hosting a meeting where this information will be presented to people from all areas of the industry. The audience will include nutritionists from the major feed companies as well as representatives from the crushing industry. At that time we will be addressing any of the concerns raised and further explaining the findings. If the crushing plants change there process today, but the new meals have not been tested, the nutritionists will assume the meal has not changed and will not be willing to pay the additional 10% for the meal. Therefore we feel it is imperative that multiple samples from every plant be collected and tested after they have had a chance to adopt the new recommendations.

Upon showing the non-toasted meal product to potential customers from several international feed companies they became very interested and wanted to know how soon we could produce this product. Before we attempt to produce and sell a non-toasted product we need to determine if there is any merit to toasting the meal. In addition, we need to determine how much of the untoasted diet can be added to the diet.

## PRODUCTION OF A NON-TOASTED YELLOW COLOURED CANOLA MEAL PRODUCT

As discussed earlier in this document, the dark color of canola meal is as a result of browning during the toasting stage. Production of a non-toasted product should be a simple procedure. To produce the non-toasted product for our experiments we simply removed sample from the solvent extractor and allowed the hexane to evaporate over a 24 hour period. Crushing plants do not have the luxury of time, but by simply

shutting off the purge steam in the desolventizer toaster (DT) they should be able to desolventize without browning.

The desolventizer toaster (Figure 37) is basically a sealed cylinder with 5 or 6 heated plates. The solvent laden material (marc) enters the DT from the top and falls on the first plate where it encounters a steam heated surface. The product is then forced through the machine by the incoming product and the movement of sweep bars. The product is pushed off one plate and falls to the next and so on. The last plate has a series of perforations where saturated steam is purged through the meal resulting in the toasting process. As the hexane is evaporated, the marc remains about 80°C (the boiling point of hexane). However, as soon as the hexane has evaporated, the meal temperature rises very quickly. The combination of the moisture and high temperatures encountered on the last plate results in the browning process.

The toasting process significantly increases the cost of canola processing since it uses large amounts of steam for sparging. In addition, the dryer cooler must remove the moisture imparted on the product by the sparge steam. Therefore, elimination of the toasting process by eliminating sparge steam would significantly reduce the costs associated with processing.

There are three main reasons for the use of spurge steam in the DT, to reduce glucosinolates, to eliminate residual myrosinase activity and to reduce residual hexane content.

The steam does reduce the level of glucosinolates in the meal but are the levels in the seed high enough to cause a problem. As long as reasonable limits are set on canola meal inclusion levels, even at the higher glucosinolate content there should not be a problem. Of course before trying to sell a non-toasted product commercially, it will be necessary to conduct feeding studies to determine how much can be included in the diet of monogastric animals. In addition, it will be necessary to perform feeding studies with ruminant species using the same non-toasted product.

The toasting process does ensure there is no residual myrosinase activity in the meal, however, the cooking stage earlier in the process is designed to specifically eliminate this enzyme. It hardly makes sense to reduce protein quality and meal value to do something that can be easily done earlier in the process with out any negative consequences.

There are some indications that steam injection does assist in the volatilization of the hexane and therefore reduce residual hexane content. We spoke to the manufacturers of the desolventizer toaster (Crown Iron Works) and they indicated that it is entirely possible to safely remove the hexane without toasting. In fact the engineer said they designed the system to toast the meal and cause browning because that is what the industry has demanded for the last 30 years. To desolventize without toasting

however, may require some modifications of the existing DT's. To assist the industry in producing a low hexane non-toasted product we are proposing an experiment where toasting without steam is tried first on a pilot scale. From the pilot scale the crushing plants could determine what types of changes would be required to their existing plants.

Toasting the meal does result in the production of "by-pass" protein for ruminants and therefore the non-toasted product may be less desirable for cattle feed. If the industry chose to sell to the cattle market, some plants could continue to use the current process. However, the existing process is more expensive due to the steam consumption and the meal will have a lower value than the new non-toasted meal. If the industry chose to produce both, product differentiation would not be difficult since the non-toasted product is clearly yellow in color while the toasted product is markedly brown.

## CONCLUSIONS

The major factor contributing to the value of canola meal is its low amino acid availability. Commercial toasting conditions are significantly reducing meal quality and value and should be reduced if not eliminated. Some varieties of canola appear to be more resistant to heat damage and future selection could be made on this basis, however, it would be more prudent to reduce the degree of toasting during processing. Elimination of toasting completely results in a light colored product, with very good amino acid availability, however, additional research would be required before a product of this type could be produced commercially.

If the industry adopts the changes to the process proposed in this report the value of the canola meal would be at least 10% higher than it is currently sold for. In addition, reducing the degree of toasting also reduces the costs associated with processing further increasing profit margins. The guidelines for testing meal quality should be changed to ensure a higher quality product is produced. NDIN provides the most accurate predictor of amino acid availability measured so far and crushing plants should produce meals with no more than 10% NDIN.

Additional research is needed to support the change in the industry. Once the crushing plants have had a chance to convert to the new process, meal samples should be collected and assayed for amino acid availability. If the quality is consistently higher, and we expect it will be, then nutritionists can be informed of the change and they can start formulating on the basis of higher nutrient utilization. Once the customers are comfortable with the new meal quality, they will be able to pay more for the meal since they are receiving more usable nutrients. We also need to further investigate the possibility of producing and selling a non toasted meal product. Non-toasted meal should be produced in a pilot plant such as POS to determine the procedure. In addition, the meal produced should be fed to animals to determine if any toxic factors are present in the absence of toasting.

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Simbaya, J., Slominski, B.A., Rakow, G., Campbell, L.D., Downey, R.K., and Bell, J.M. 1995. Qualtity characteristics of yellow-seeded Brassica seed meals: protein, carbohydrates, and dietary fiber components. J. Agric. Food Chem. 43:2062-2066.

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## 4. Personnel

Mr. Rex Newkirk was hired full time May 1st, 1997 as a Professional Research Associate. Mr. Hong Yu Qiao began studies towards a Ph.D. in September, 1997.

## 5. Equipment

No equipment has been rented or purchased out of the funds from this ADF grant.

## 6. Project Developed Materials

Samples of commercial non-toasted and toasted canola meal are included with this report.

## 7. Project Photos

There are no project photos to include.

## 8. Acknowledgement

On March 5th we had a grand opening of a new facility associated with the Poultry Centre. At that time we acknowledged the support of ADF for this and other projects. A poster outlining funding sources has been produced and will be used routinely by our staff to show the support we have received from ADF.

Funding from ADF was gratefully acknowledged when part of this information was presented at the annual meeting of the Poultry Science conference held in Arkansas in 1999. Mr. Newkirk was awarded a Certificate of Excellence for his presentation ot this material at that time. Acknowledgement of ADF's contributions to this project was also announced when parts of this research was presented to individuals participating in the Canadian Feed Ingredient Program put on by the Canadian International Grains Institute.

The contributions of ADF towards this project will be acknowledged at future meetings including discussions with canola processors. A meeting with all persons involved with canola production, crushing and use is currently being planned for November and ADF's generous support will be acknowledged at that time.

**9. Expense Statement**

A statement of expenses has already been forwarded by the University of Saskatchewan.

**Figure 1. Lysine availability in Canola and Soybean Meals.**

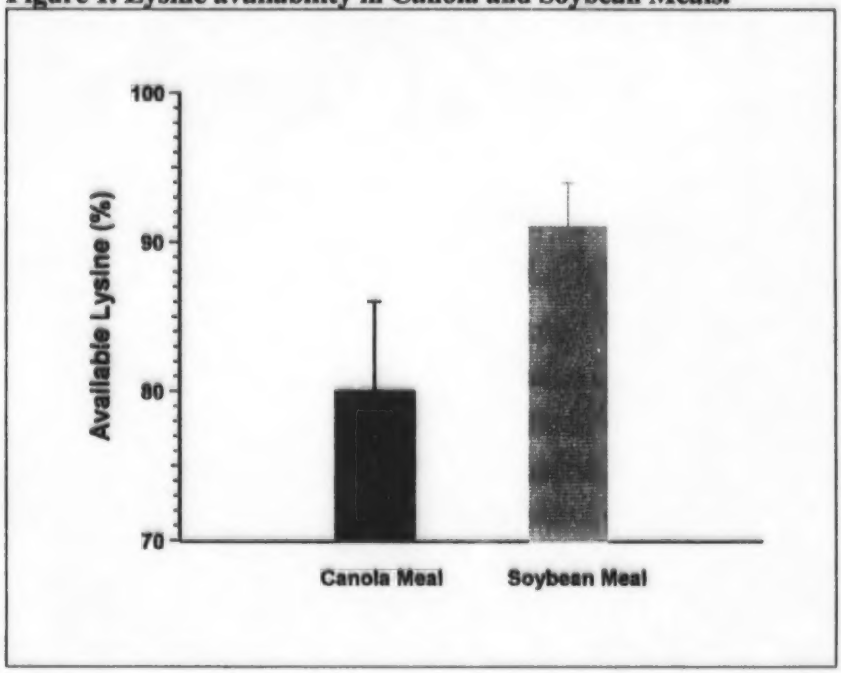


**Figure 2. Crude protein content (as is) for fat free meal derived from 30 varieties of canola.**

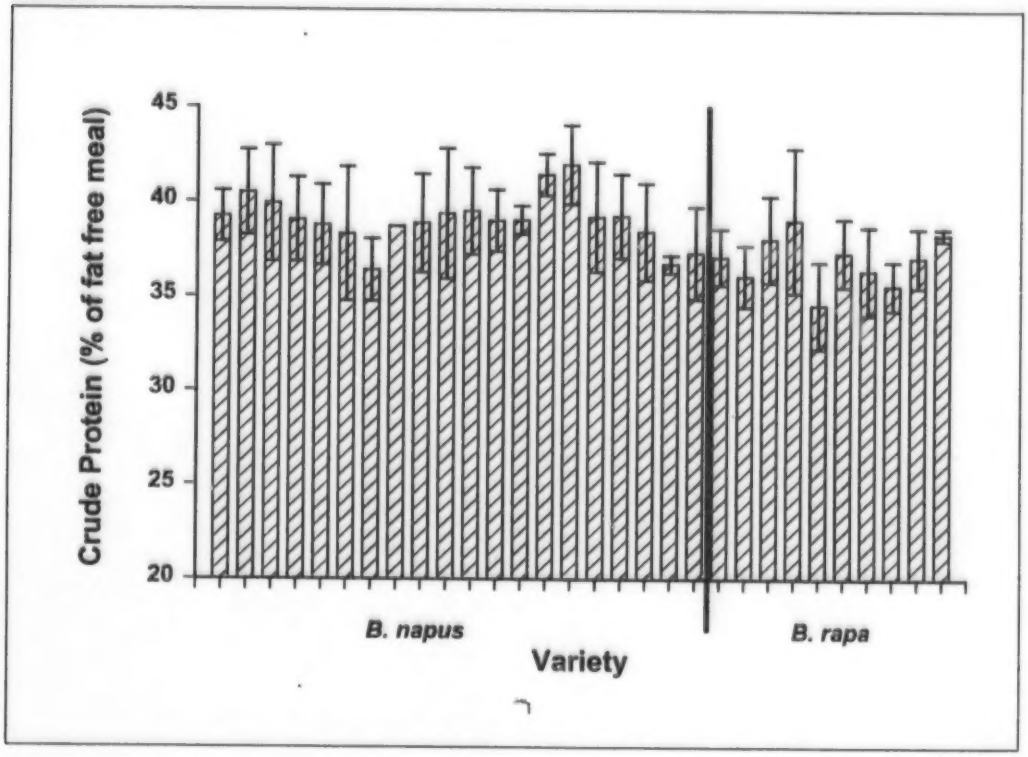


**Figure 3. Crude protein content (fat free, as is basis) of commercial canola meal samples before (marc) and after toasting (meal).**

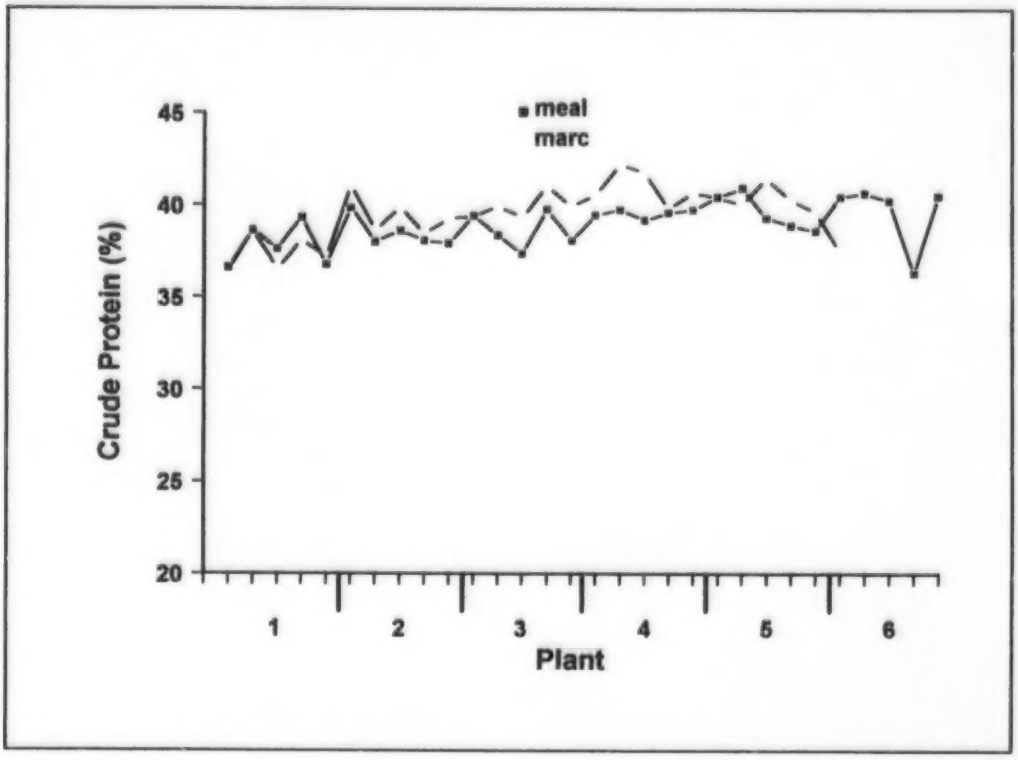


**Figure 4. Effect of processing temperature on NDIN content of canola meals.**

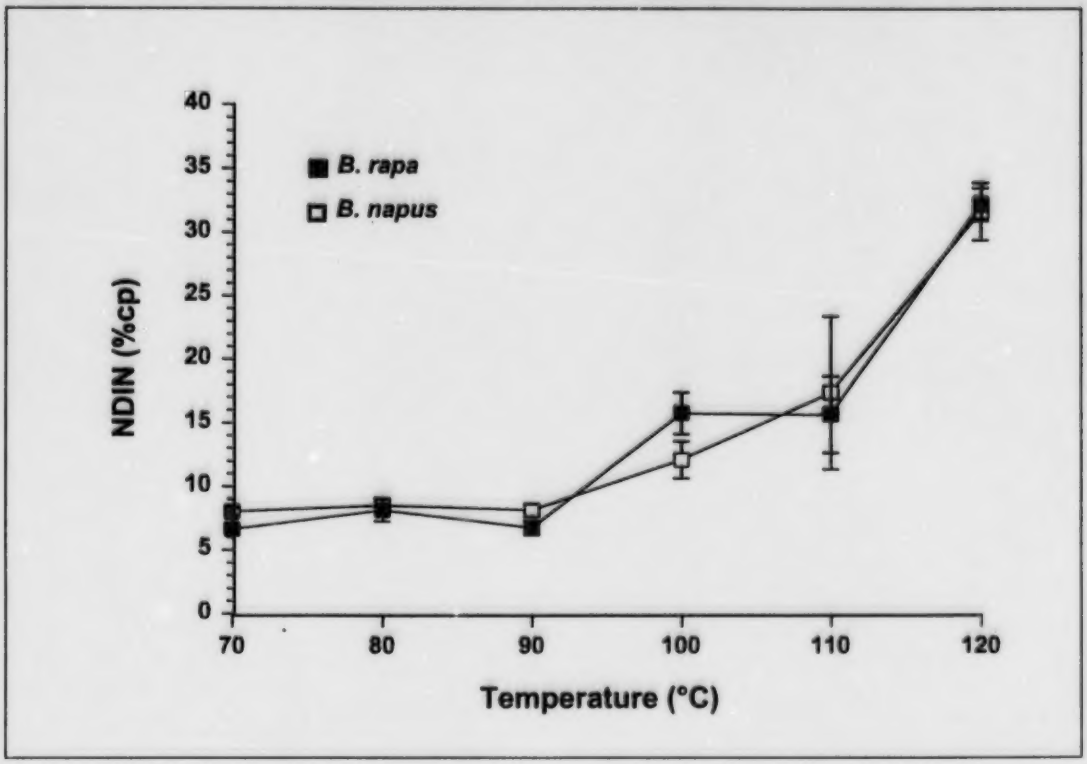


**Figure 5. Effect of temperature and duration of toasting on NDIN content in *Brassica napus***

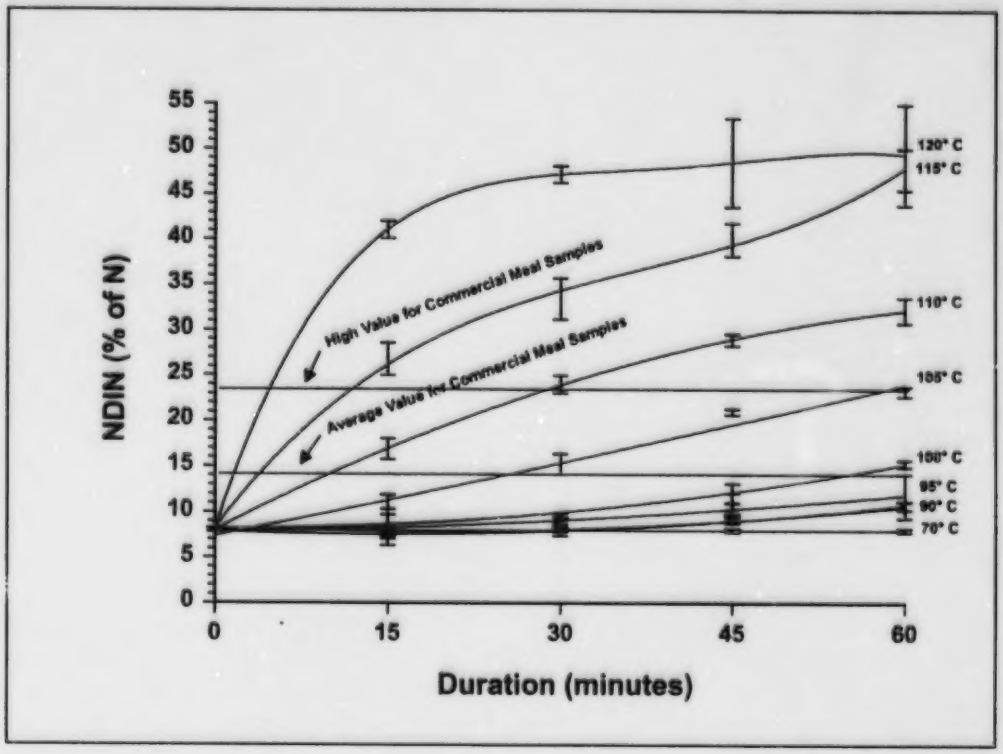


**Figure 6. The effect of temperature and duration of toasting on NDIN content in *Brassica rapa***

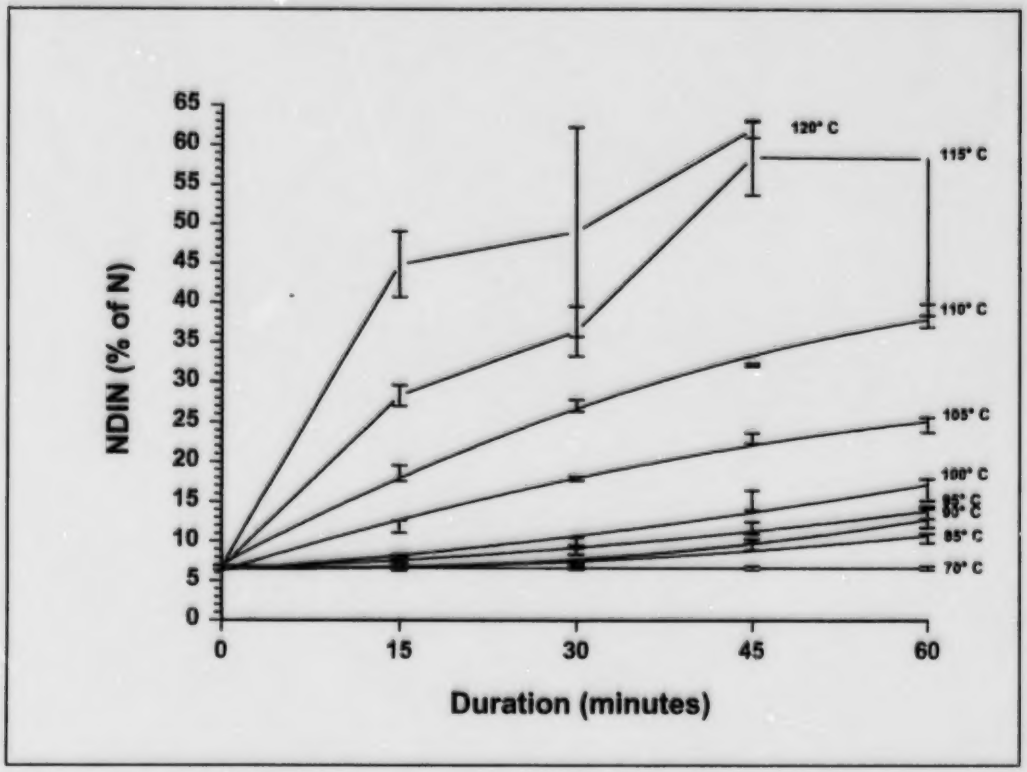


**Figure 7. Stages of commercial pre-press solvent extraction of canola meal.**

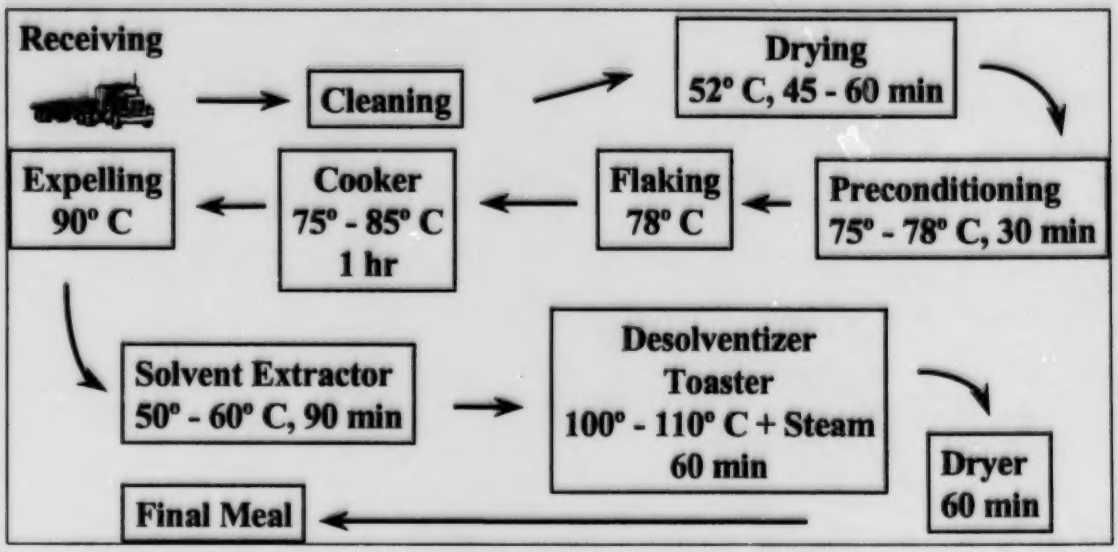


**Figure 8. Lysine content of canola products before (marc) and after toasting (meal).**

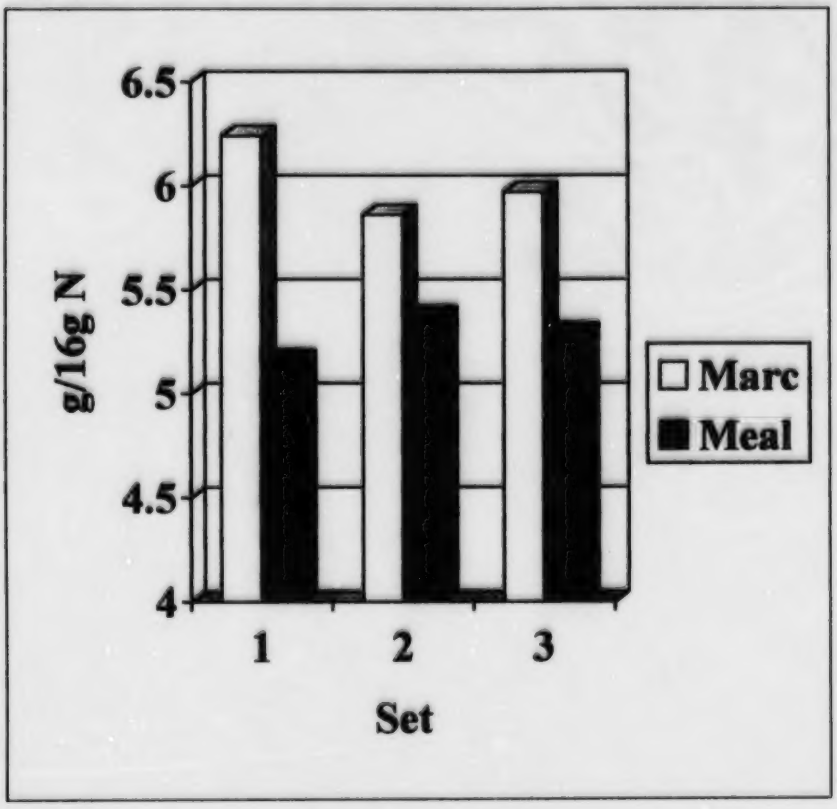


**Figure 9. The effect of processing stage on protein availability in canola meal.** Stage 1, 2, 3, 4, 5, and 6 represent meals after toasting, cooking, expelling, solvent extraction, toasting and drying respectively. The T designates the toasted meal. Shown is the mean of the three samples collected. Means with no common superscript differ signficantly P<0.05)

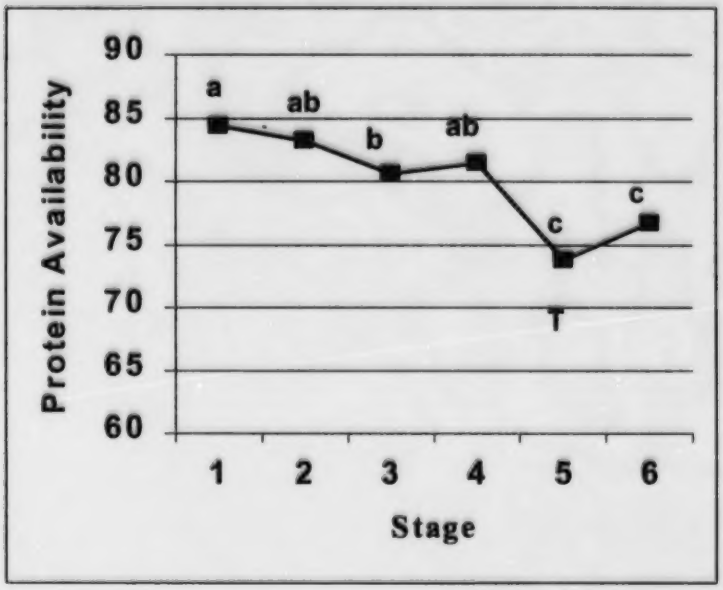


**Figure 10. Effect of processing on lysine availability in canola meal.** Stage 1, 2, 3, 4, 5, 6, and 7 represent meals after toasting, cooking, expelling, solvent extraction, toasting and drying respectively. The T designates the toasted meal. Means with no common subscript different significantly ($P<0.05$).

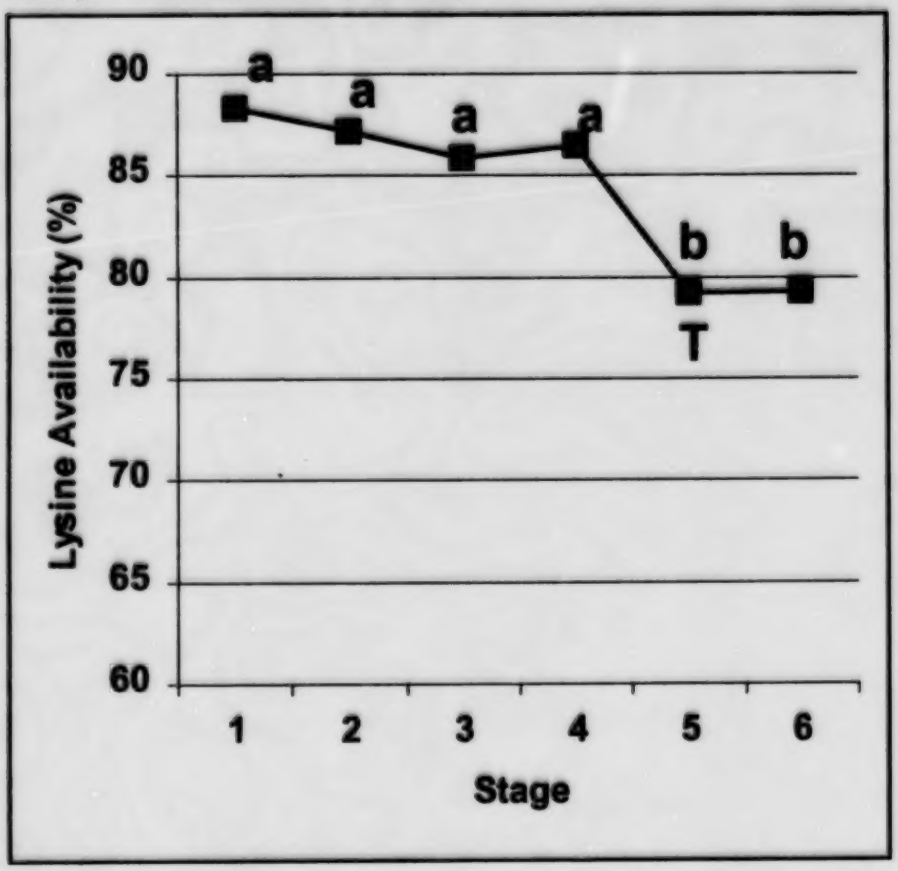


**Figure 11. Metabolisable energy (AME) of canola samples before (stage 4) and after toasting (stages 5 and 6).**

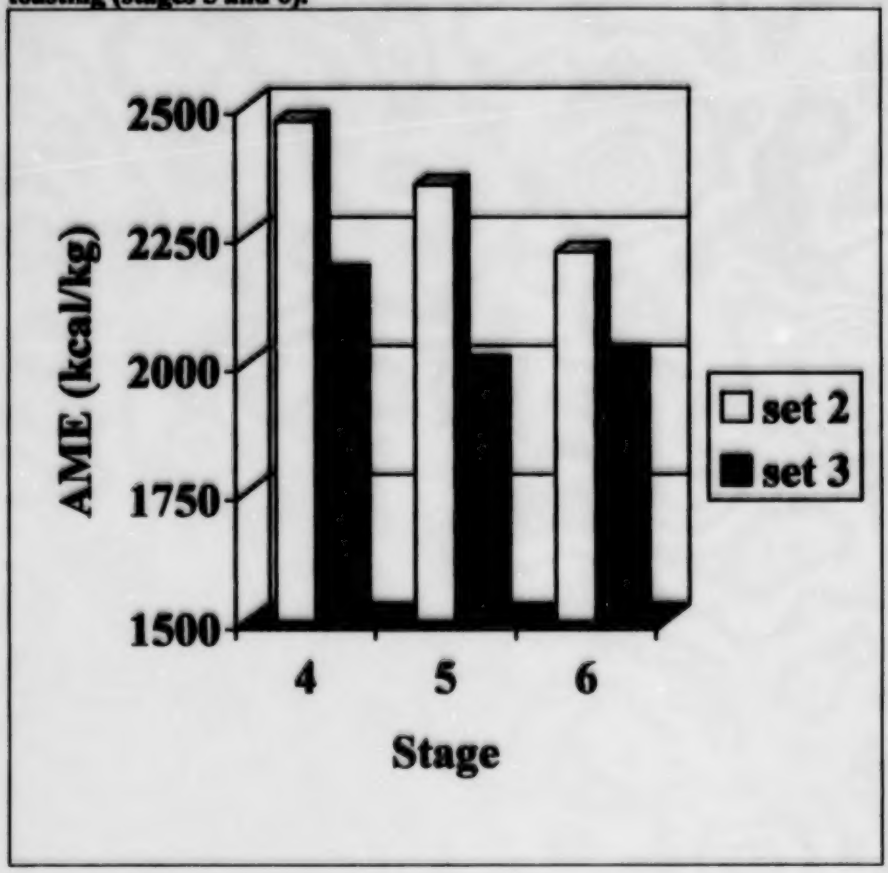


**Figure 12. Canola meal products before and after toasting.** Shown below from left to right are untoasted marc, toasted meal and final dried canola meal product.

**Figure 13. Amino acid availability in canola products before and after toasting.** Shown is the average of 26 marc samples and 30 meal samples.

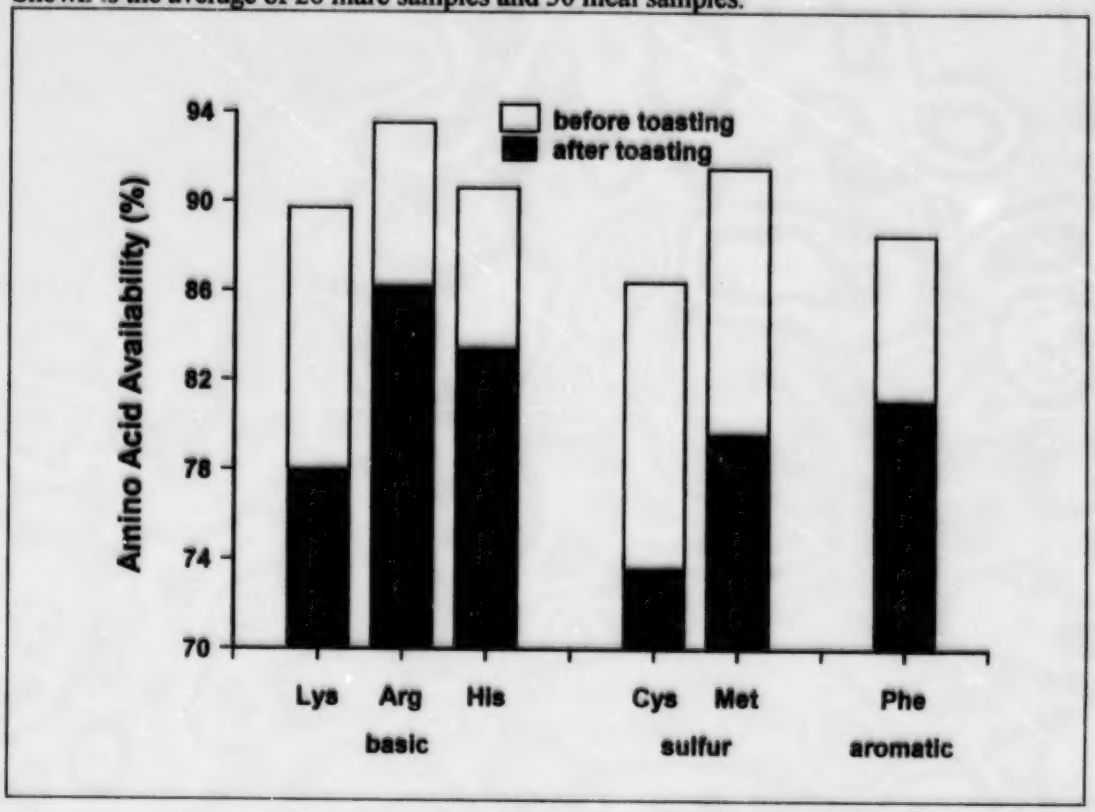


**Figure 14. Lysine availability of meals before and after toasting.**

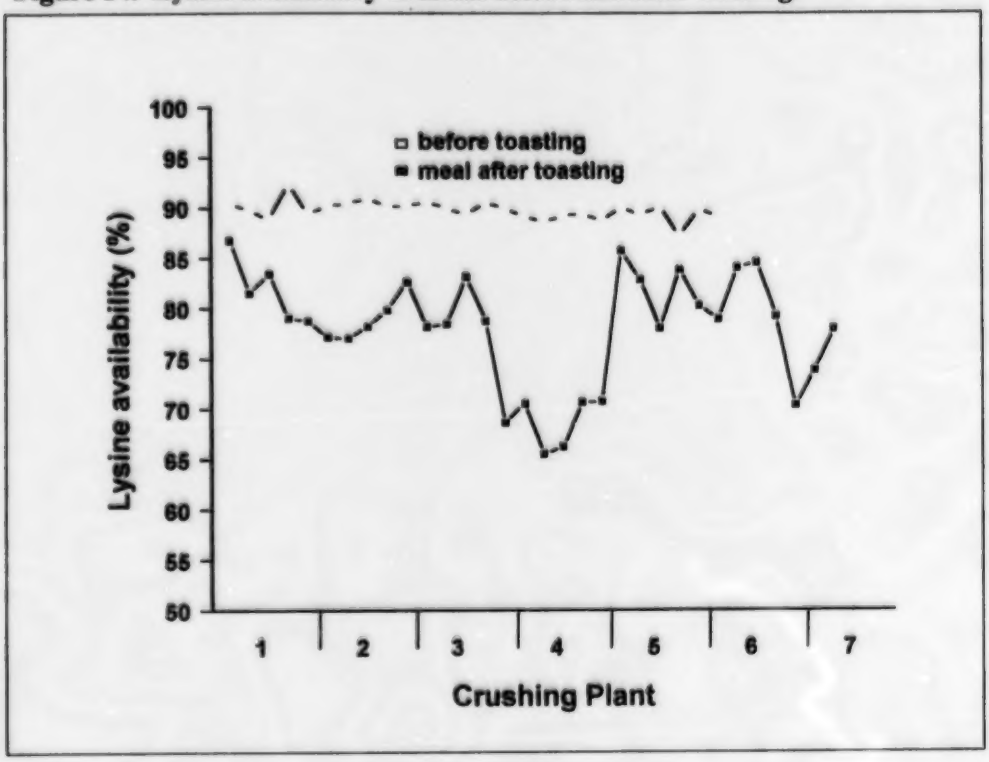


**Figure 15. Average lysine availability (± standard error) in soybean meal, canola marc (prior to toasting) and canola meal (after toasting).**

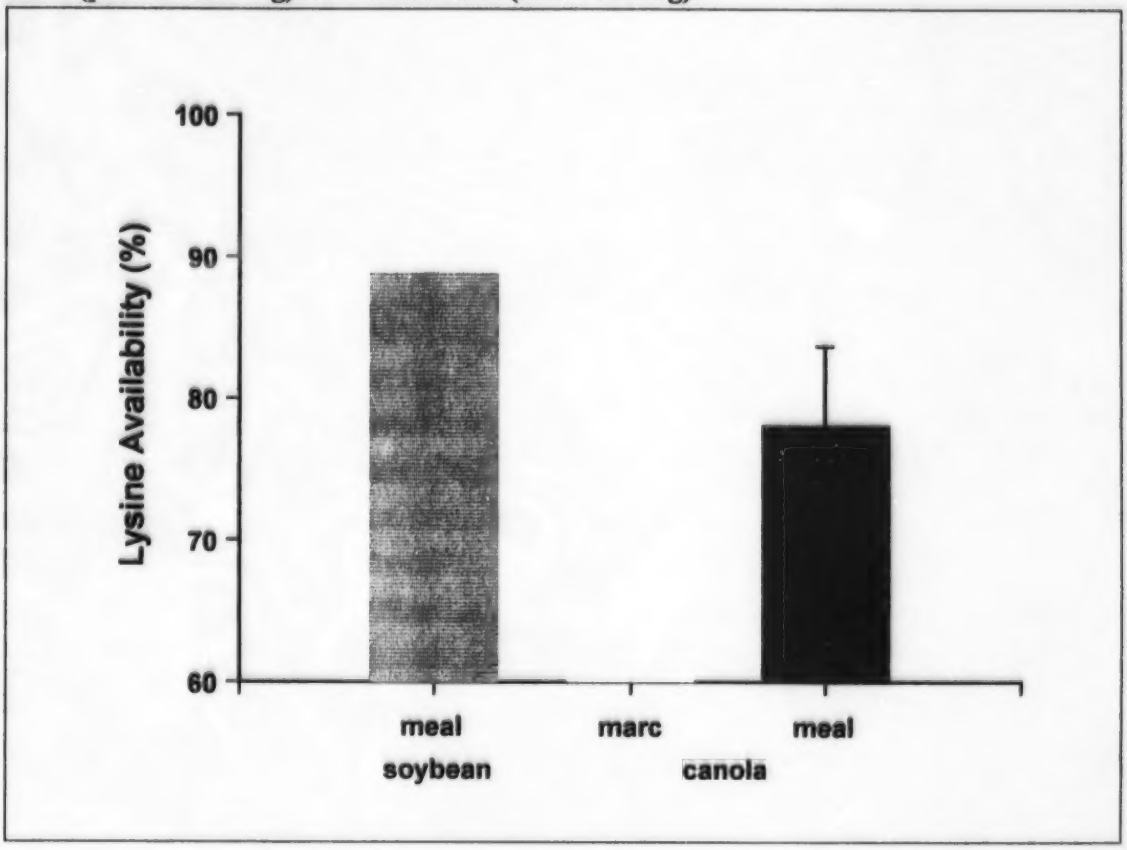


**Figure 16. Available lysine content of canola meal samples before and after toasting.**

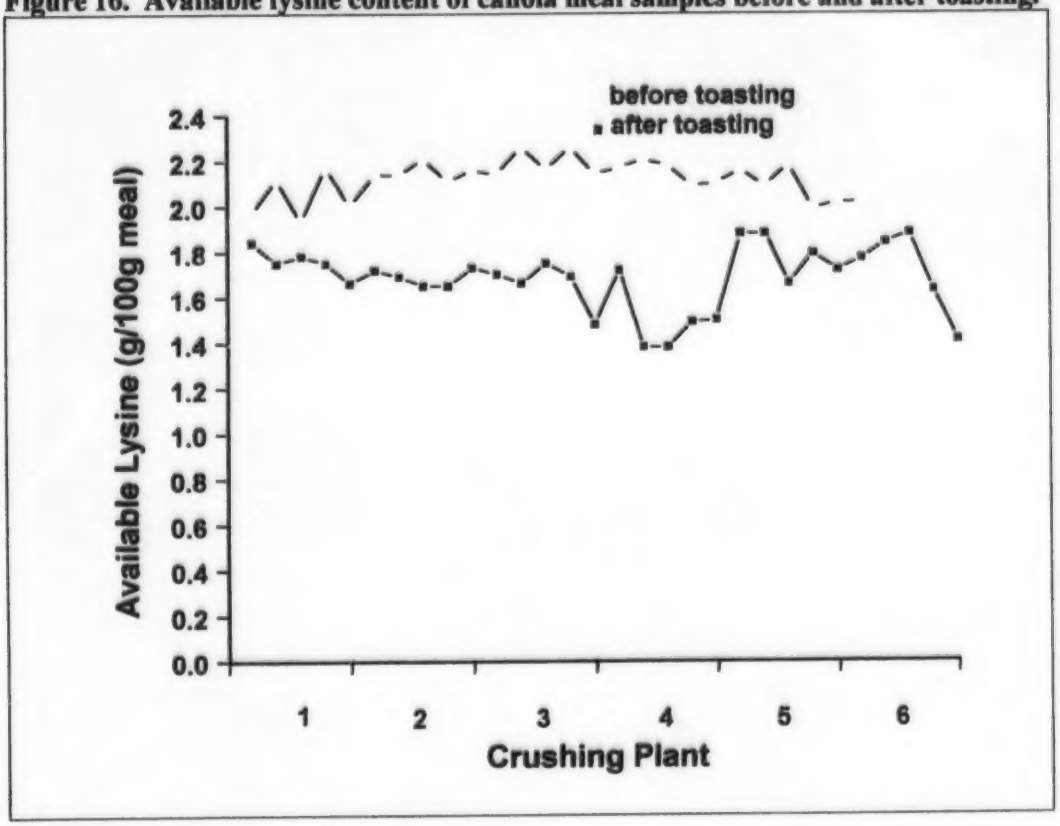


**Figure 17. Effect of toasting on the available content of the imino and aliphatic amino acids.** *** Denotes a significant effect at P<0.001.

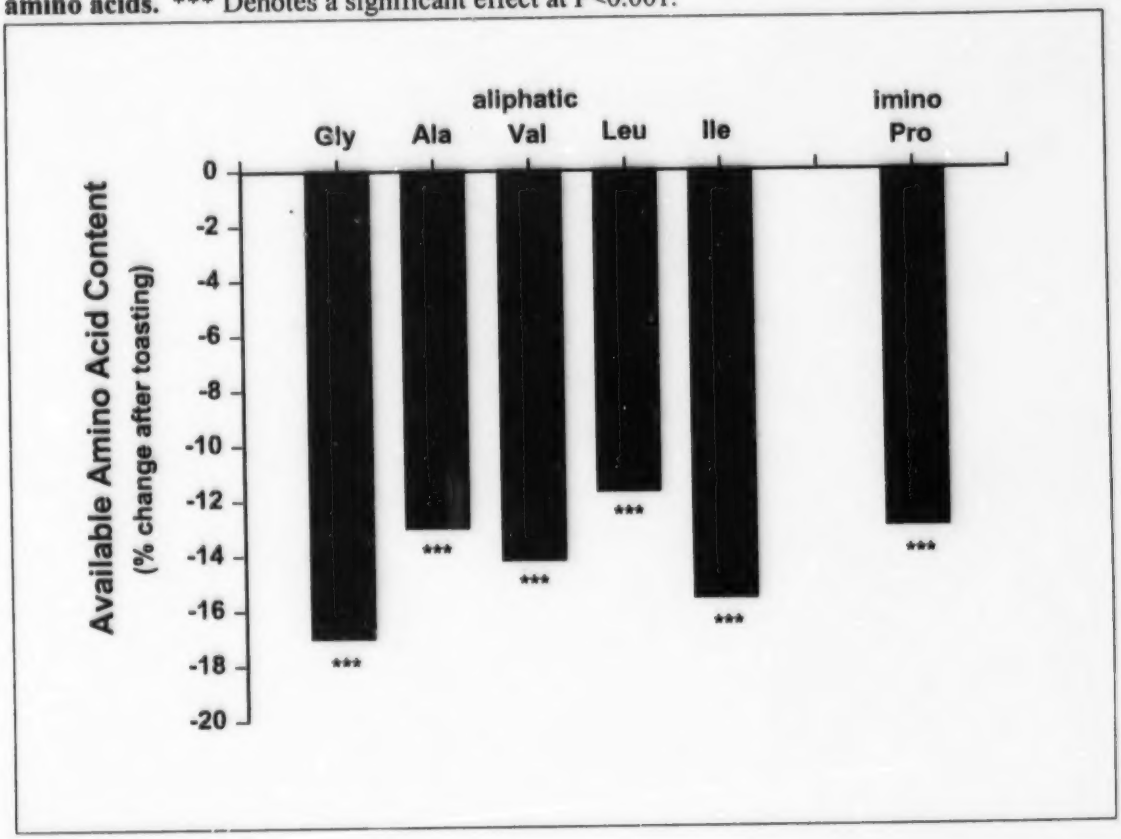


**Figure 18. The effect of toasting on the available content of the basic, sulfur and aromatic amino acids in canola meal.** P<0.001 if denoted by ***.

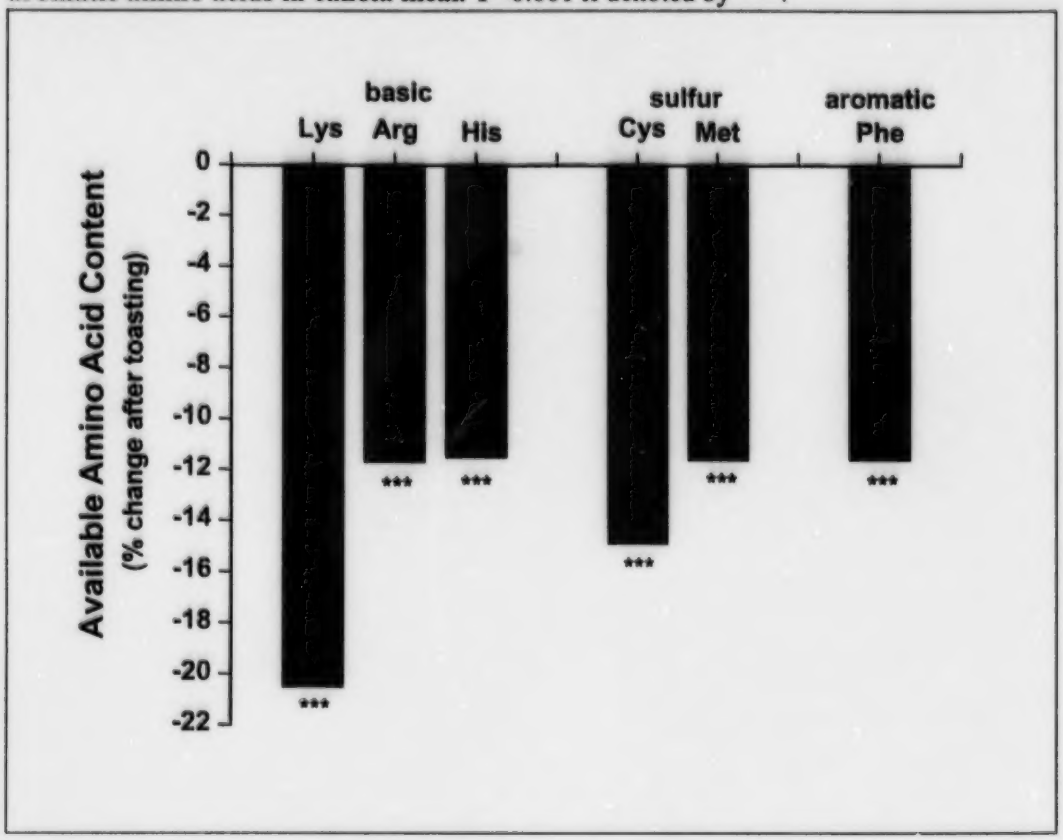


**Figure 19. The effect of toasting on the available content of the hydroxylic, acidic and total amino acids in canola meal.** P<0.001 if denoted by ***.

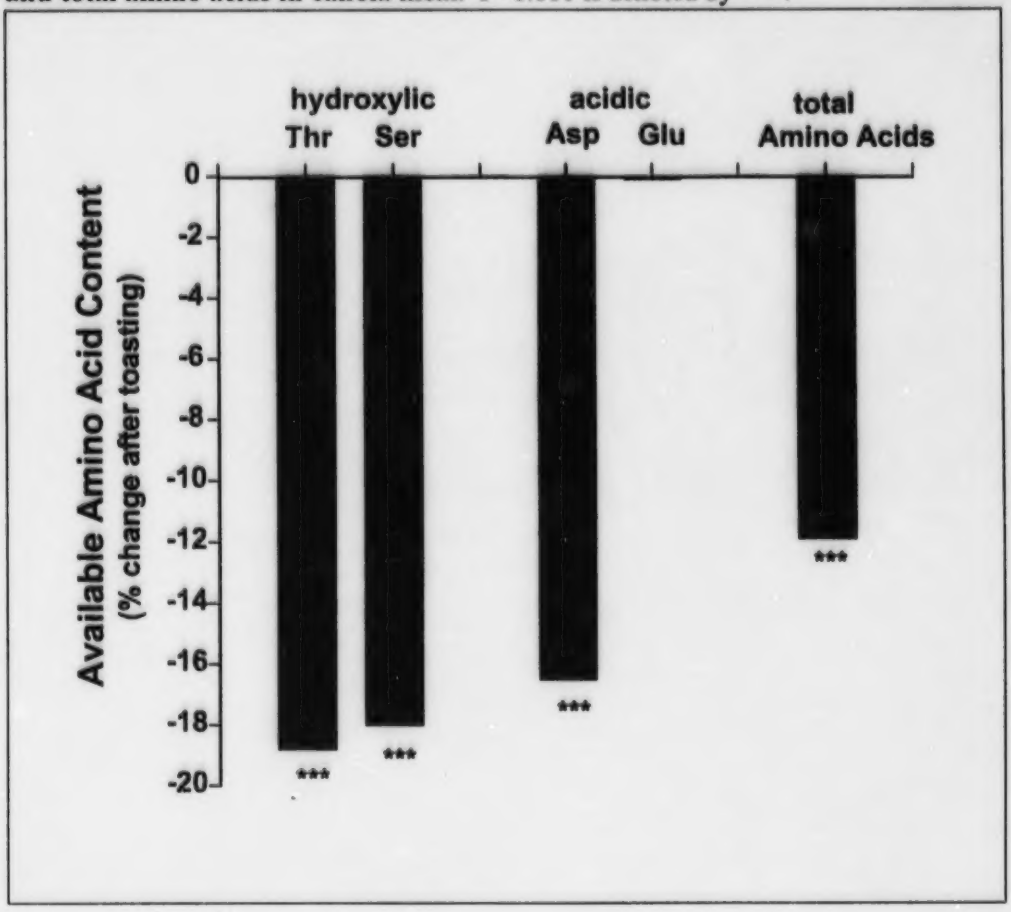


**Figure 20. Available lysine content as a proportion of the protein in canola meal before and after toasting.**

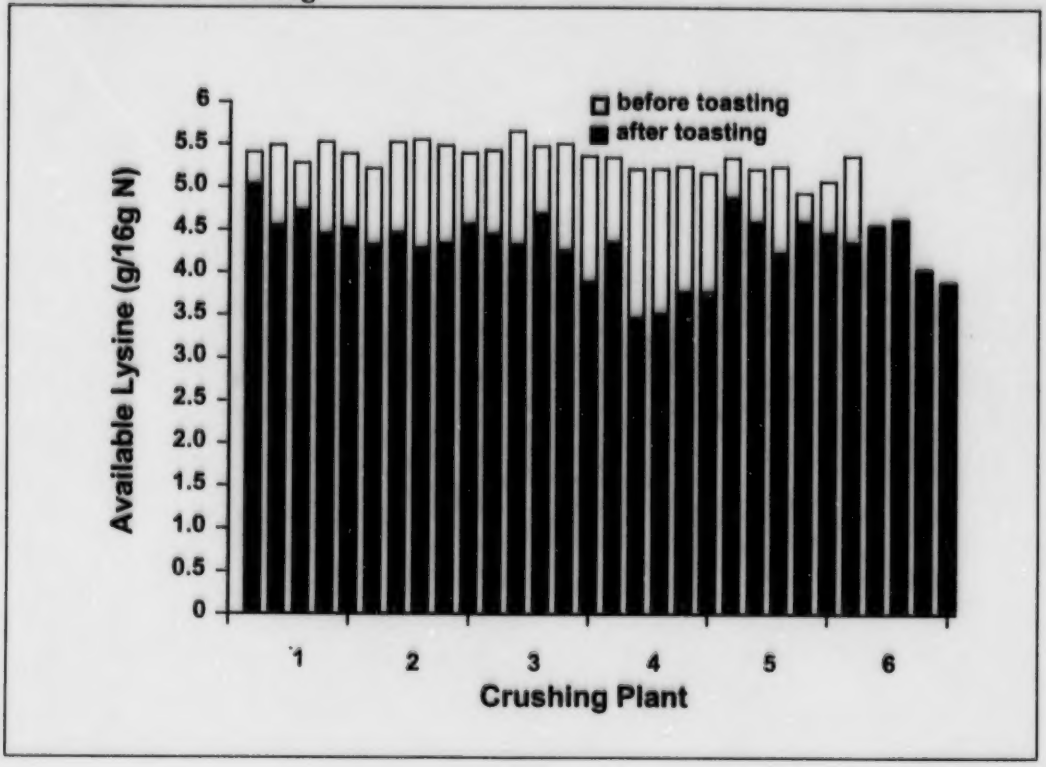


**Figure 21. Prediction of lysine availability in canola meal using protein solubilty (NSI) in 0.5% KOH.**

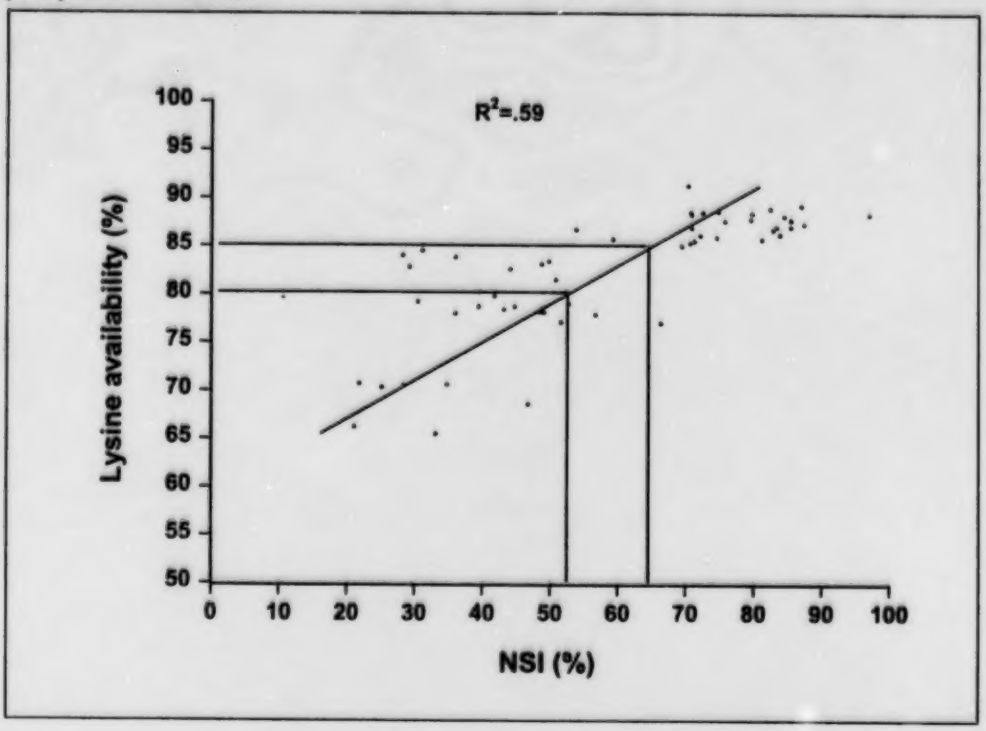


**Figure 22. Prediction of lysine availability in commercial canola meal samples using NDIN.**

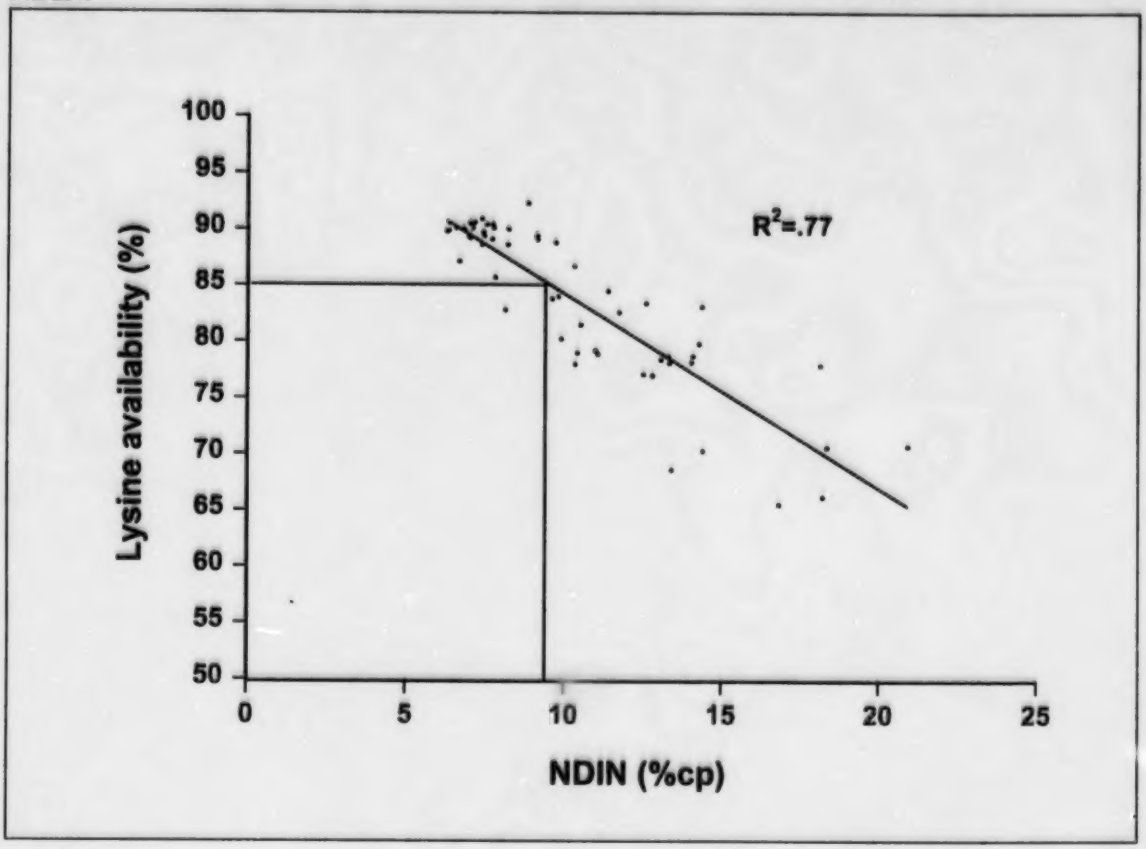


**Figure 23. Lysine availability (as predicted by NDIN) in *Brassica rapa* varieties after heating at 110°C for 10 minutes.**

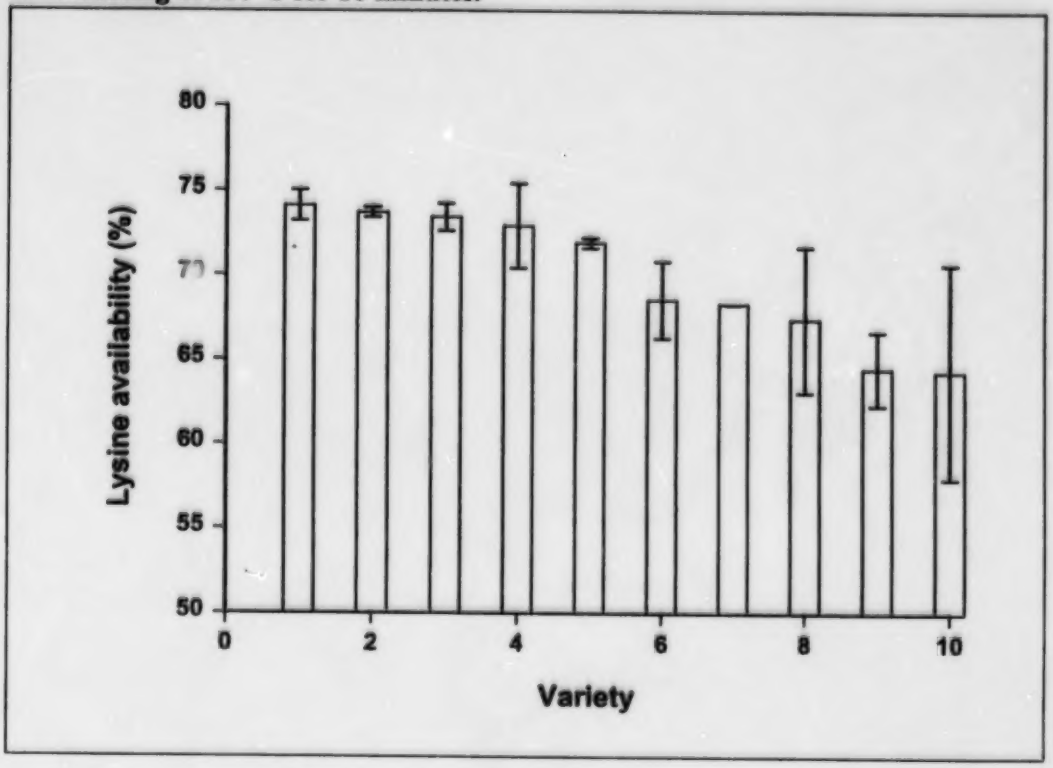


**Figure 24. Lysine availability (as predicted by NDIN) in *Brassica napus* samples after heating at 110°C for 10 minutes.**

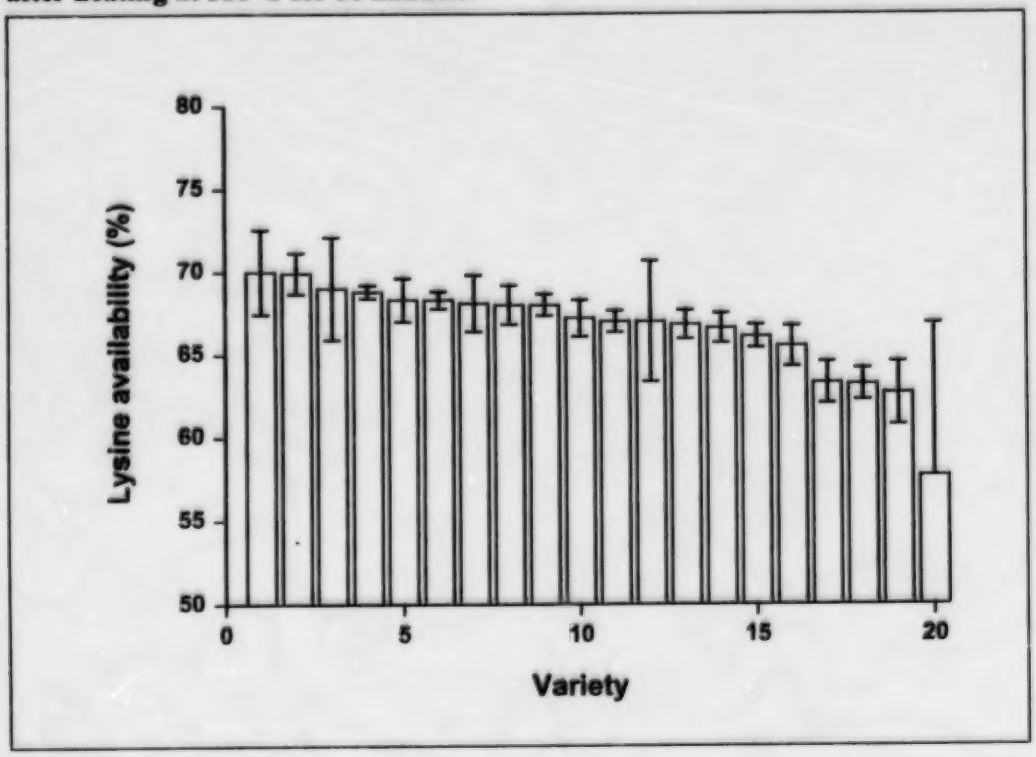


**Figure 25. Total glucosinolate levels in canola before and after toasting.**

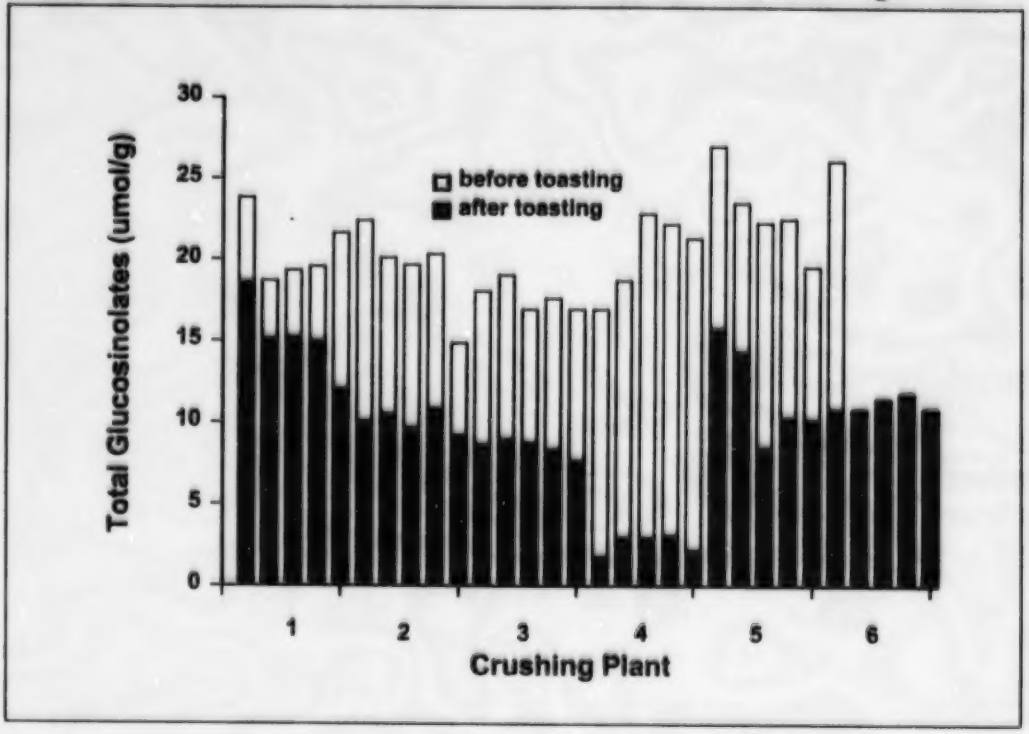


**Figure 26. Indole glucosinolate content of canola samples before and after toasting.**

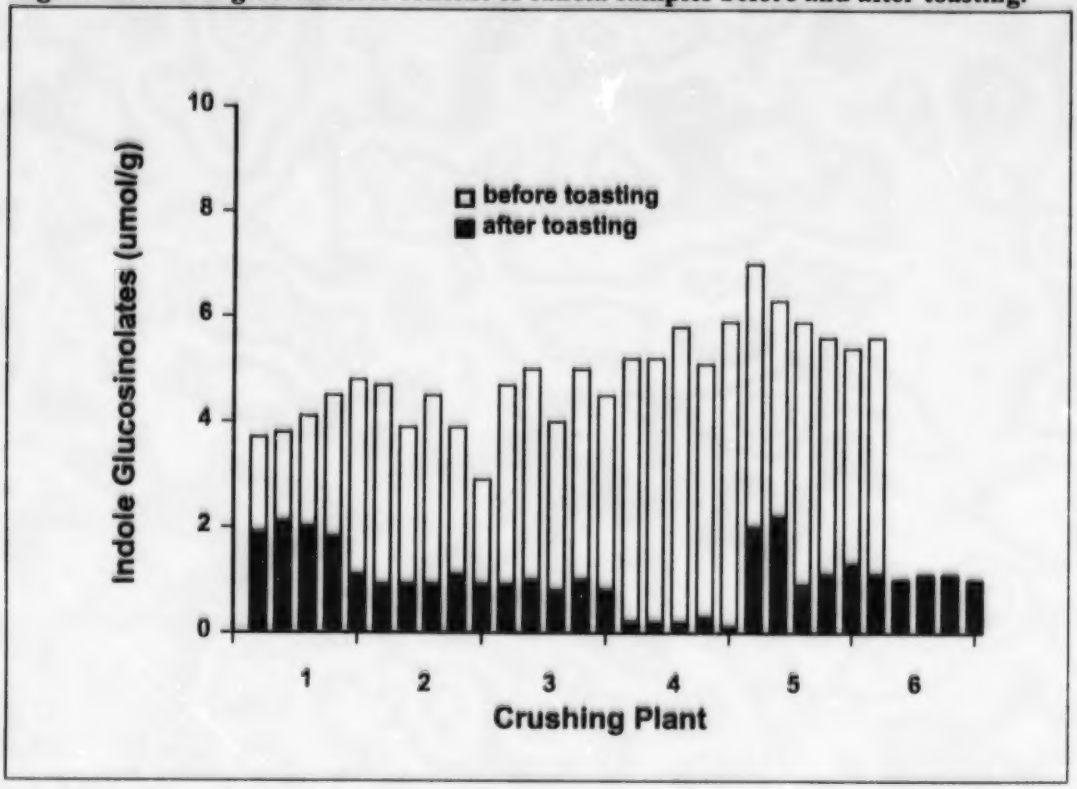


**Figure 27. Aliphatic glucosinolate content of canola samples before and after toasting.**

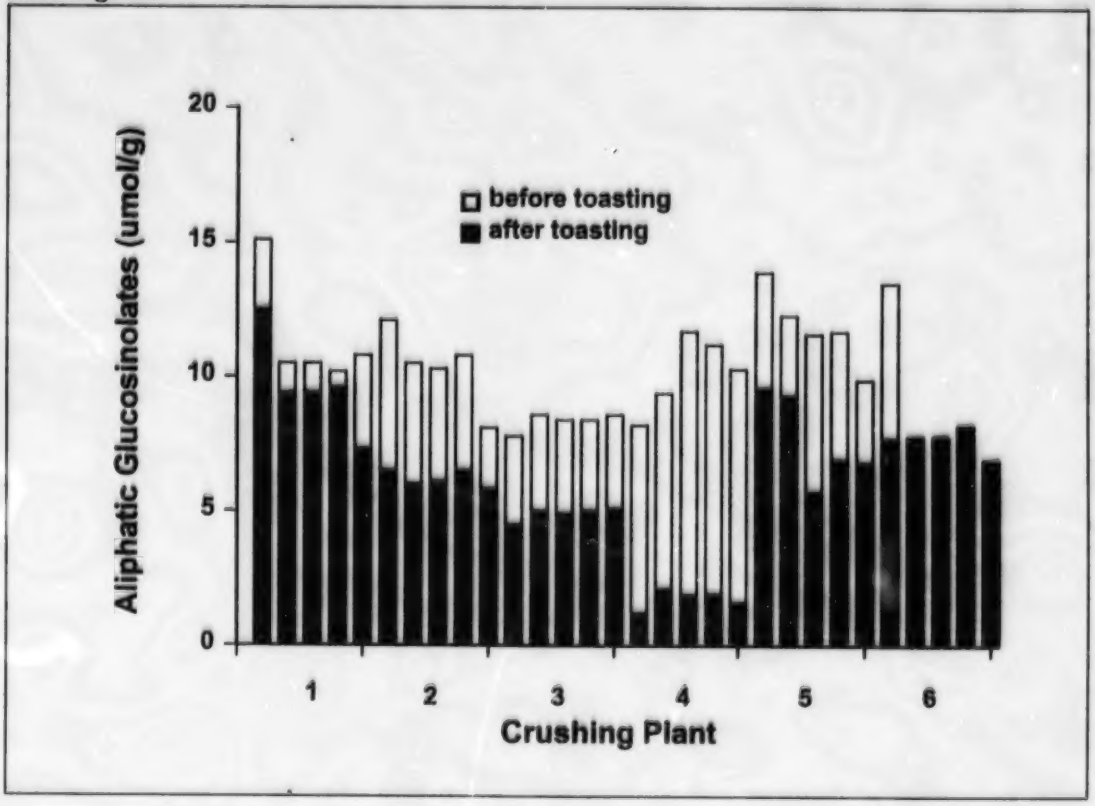


**Figure 28. Metabolisable energy (AME) of comercial canola samples before and after toasting.**

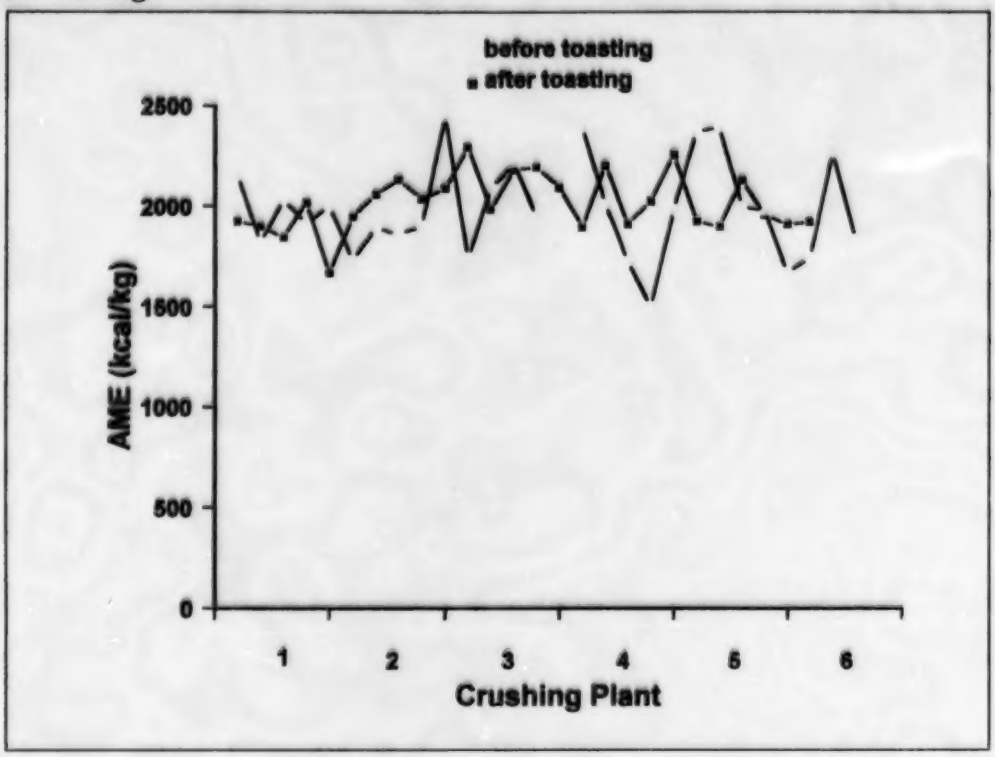


**Figure 29. Correlation of neutral detergent fiber and metabolisable energy in commercial canola meal samples.**

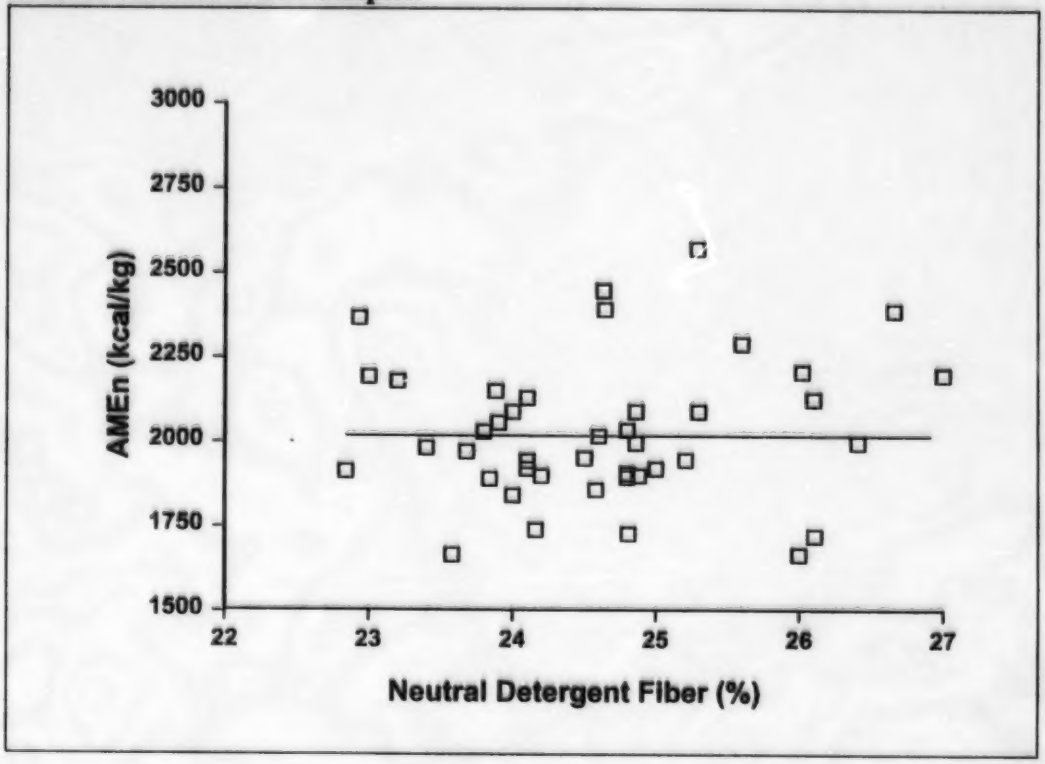
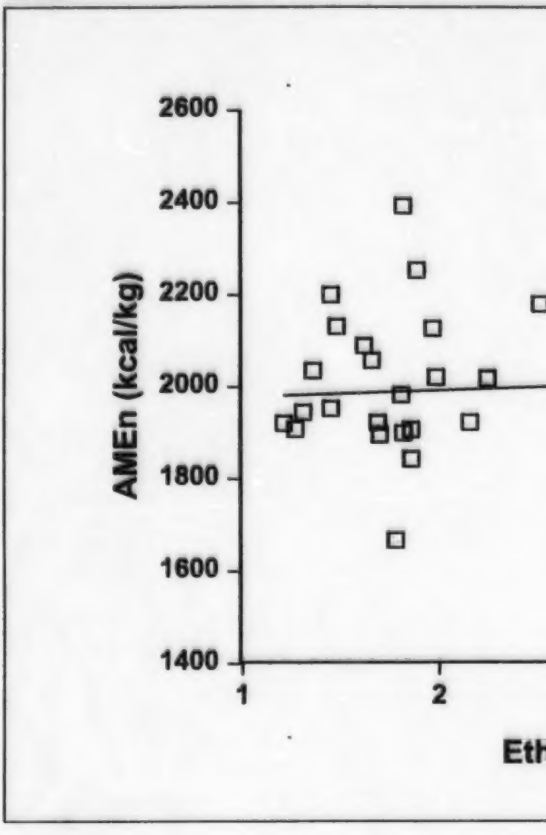


**Figure 30. Correlation between ether extra**
**meal.**



and metabolisable energy in canola

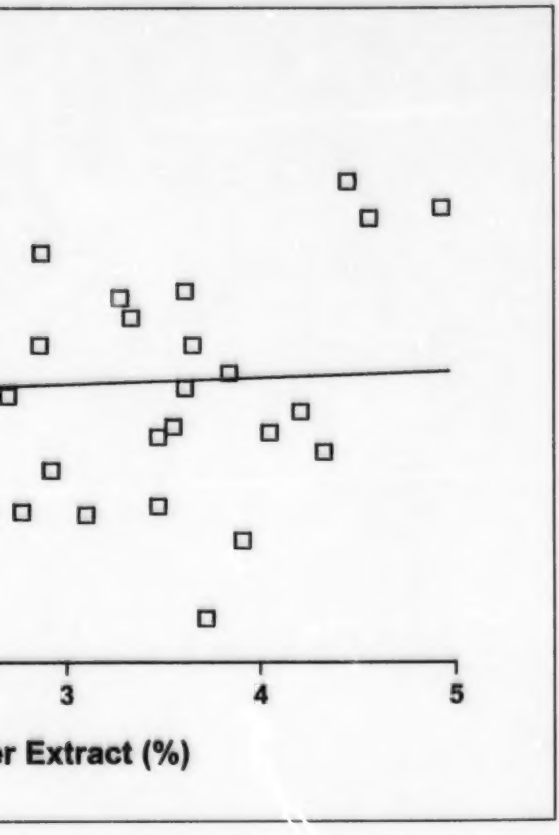
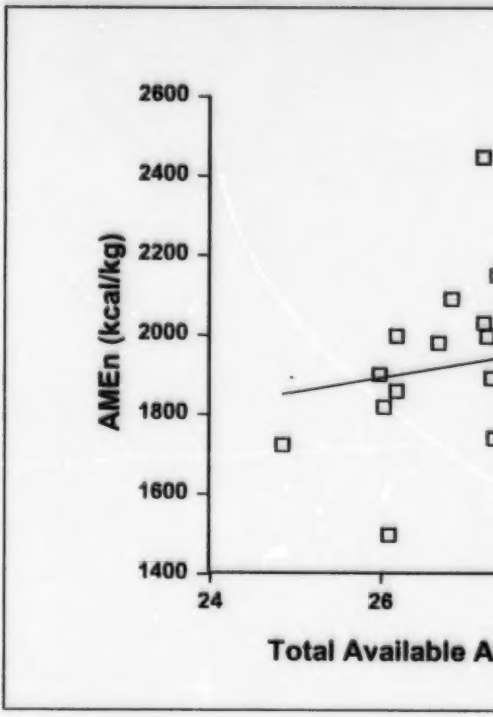


**Figure 31. Correlation between total av**
**metabolisable energy in commercial ca**



**ilable amino acid content and apparent**
**ola meal samples.**

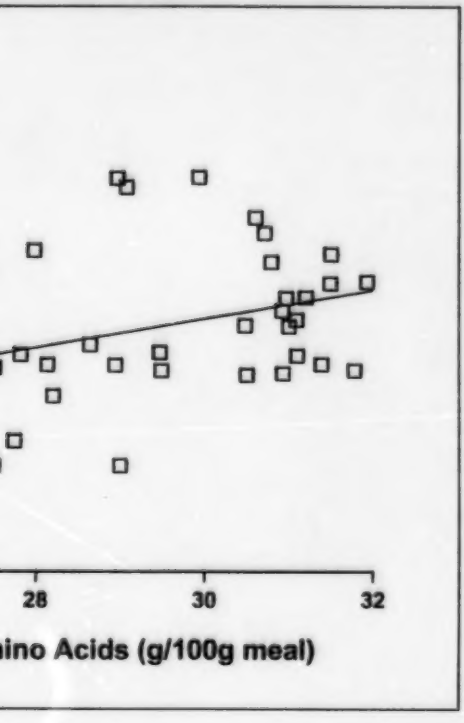


**Figure 32. Reducing sugar content (non-invertase treated) of canola meal samples before and after toasting.**

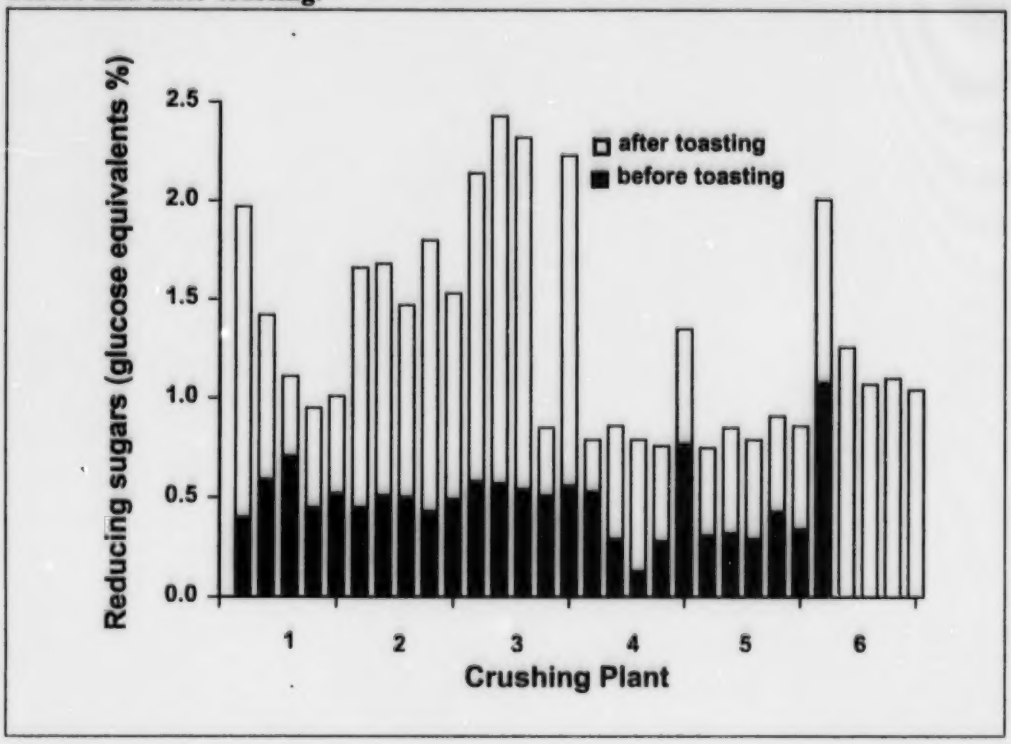


**Figure 33. Correlation between reducing sugar (non-invertase treated) content and AME in canola meal samples.**

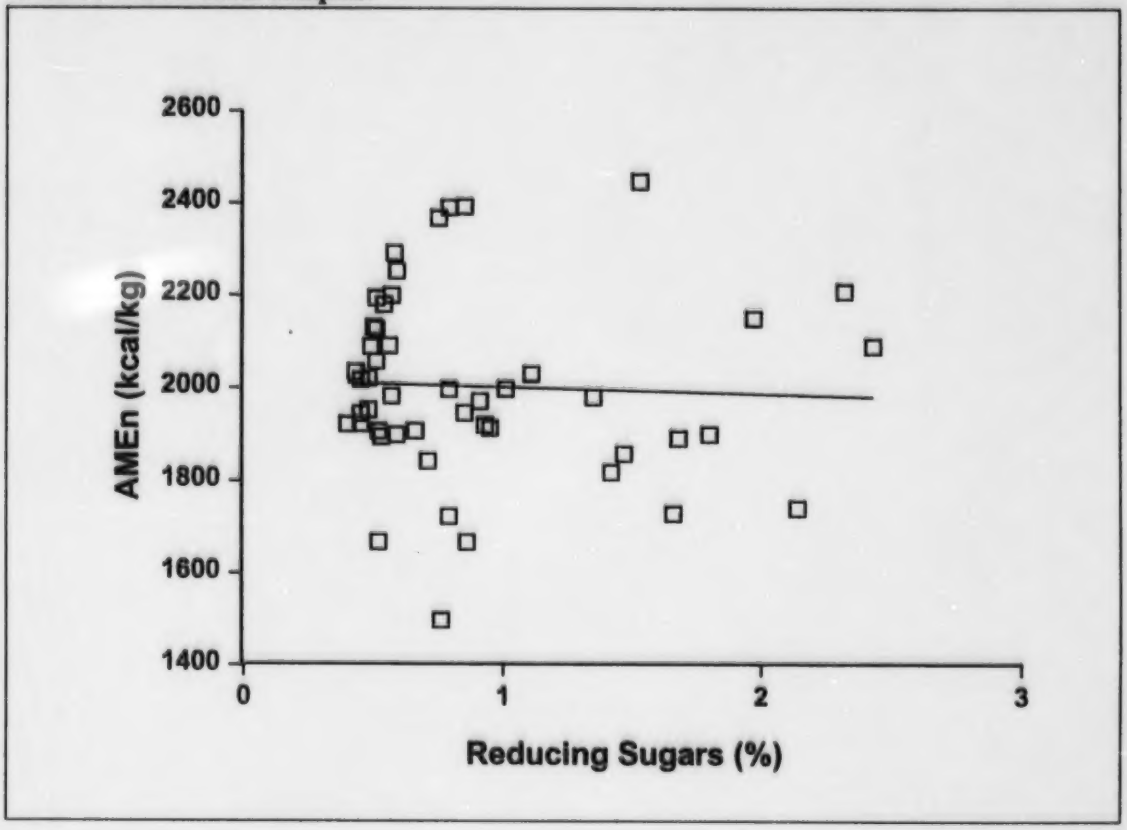


**Figure 34. Reducing sugar content of canola meal samples released by invertase treatment.**

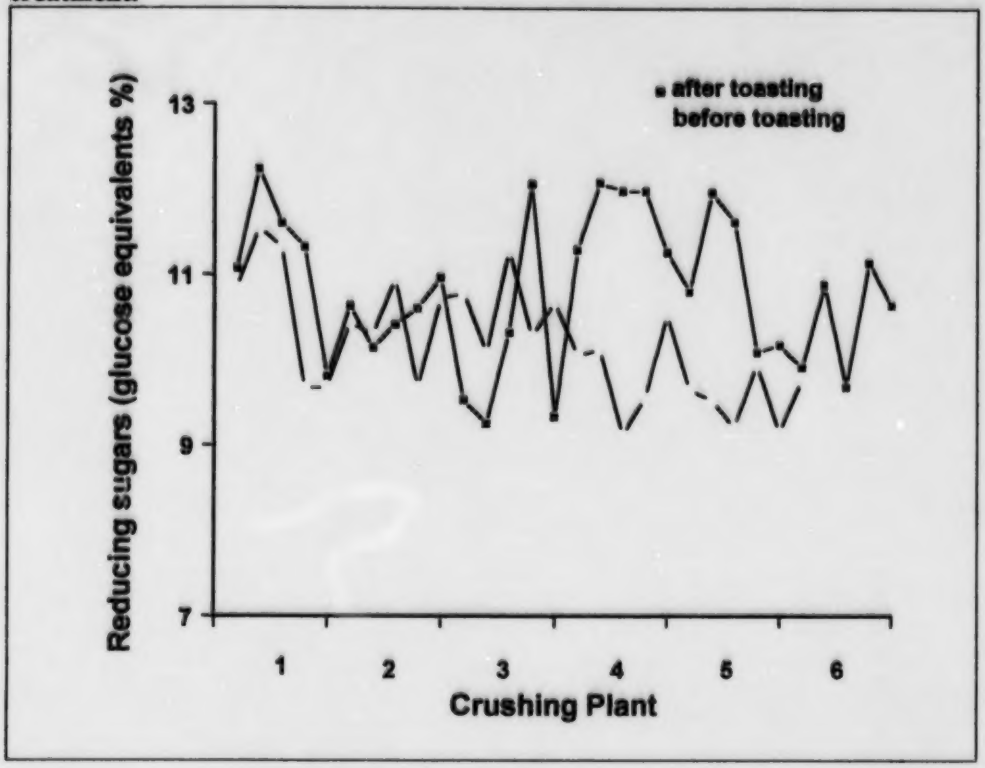


**Figure 35. Correlation between AME and reducing sugar (invertase released) content in canola meal samples.**

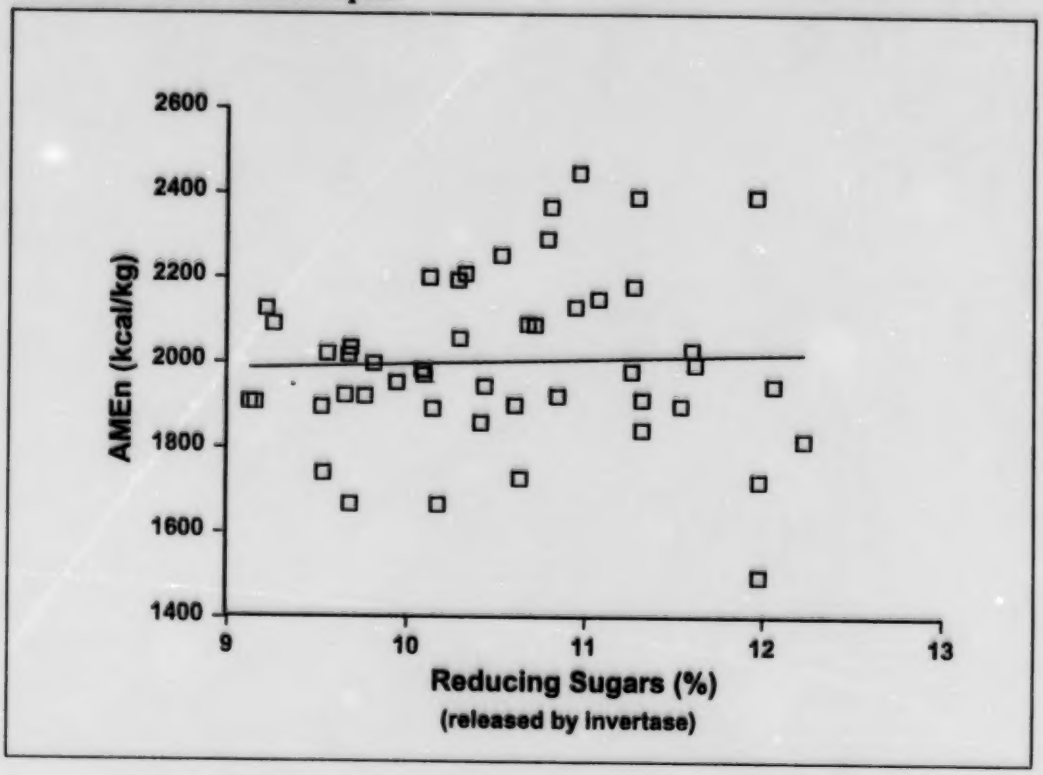


**Figure 36. Reducing sugar content (invertase treated) of *Brassica napus* and *Brassica rapa* samples.**

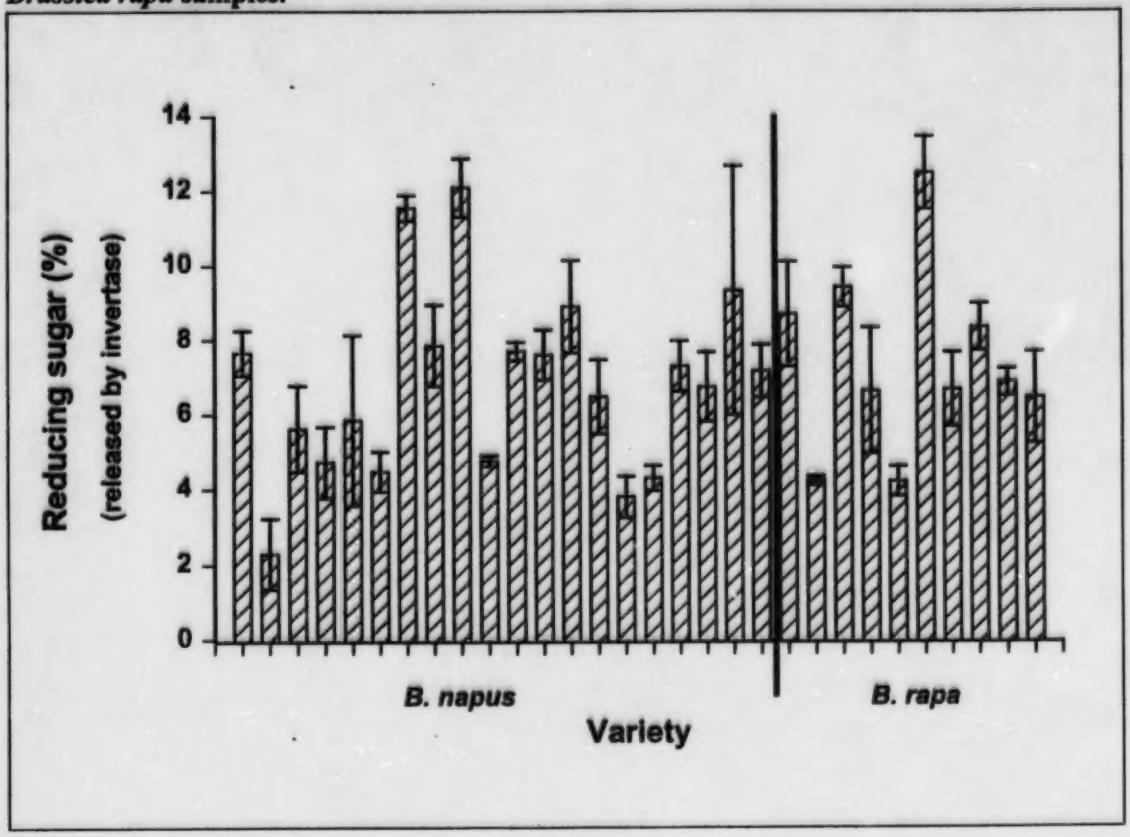
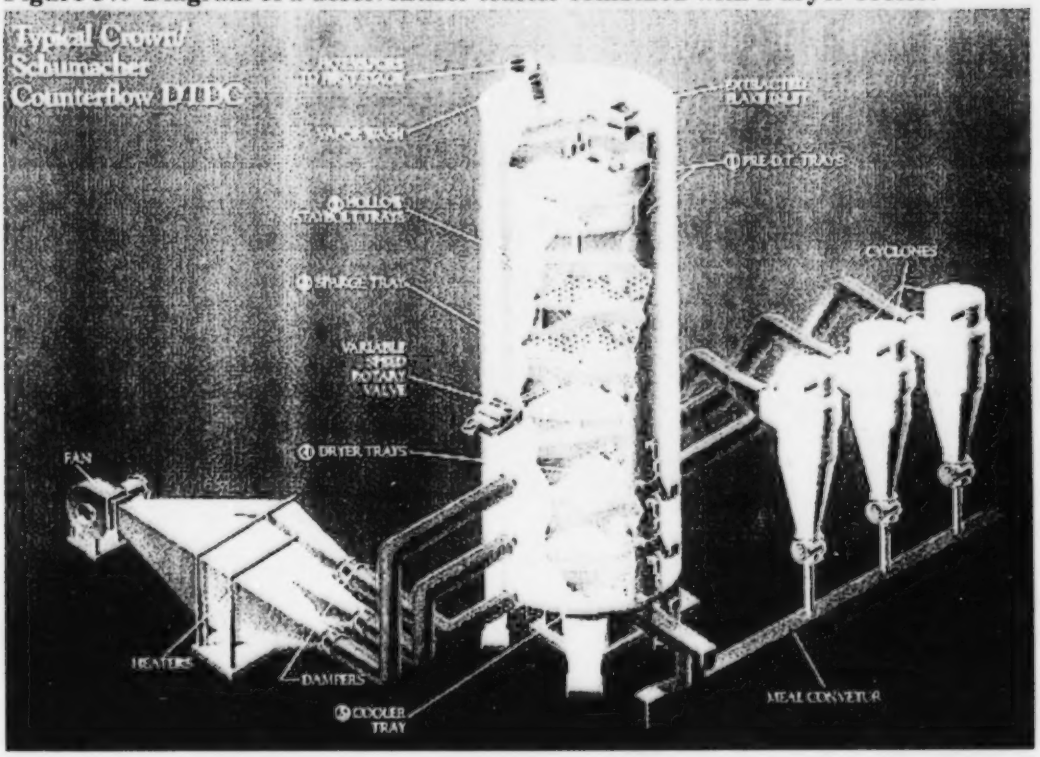


**Figure 37. Diagram of a desolventizer toaster combined with a dryer cooler.**




Source: Crown Iron Works